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Nr. 2. A. C. Johansen: ON THE DIURNAL VERTICAL MOVEMENTS OF YOUNG OF SOME FISHES IN DANISH WATERS

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KØBENHAVN
C. A. REITZEL, BOGHANDEL
BIANCO LUNOS BOGTRYKKERI
1925

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# ON THE DIURNAL VERTICAL MOVEMENTS OF YOUNG OF SOME FISHES IN DANISH WATERS

BY

DR. A. C. JOHANSEN

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## I. Introductory remarks.

When we keep plankton organisms in glasses, we usually notice that they are phototactic, that is they tend to move towards or away from the source of illumination. In agreement with this fact it has been demonstrated by various naturalists that many planktonic and nektic organisms ascend and descend in the sea in response to changes in the intensity of sunlight and moonlight. On various cruises with the Danish research steamers "Thor" and "Dana" I have been able to confirm the observations of other naturalists regarding the diurnal vertical movement of certain pelagic organisms and to add new observations in the same direction. The present report concerns in the main larvae or young of fishes caught from the "Dana" in April of 1925 on her cruise in the Kattegat, Belt Sea and western part of the Baltic.

On this cruise we made a series of horizontal hauls with Ring-trawl of stramin. At each station two hauls were usually taken, one in the upper, and one in the intermediate or lower layer. Most of the stations were taken with the object of investigating the distribution and frequency of the larvae of certain food fishes, especially the winter spawning herring and the cod. During these experiments it became apparent that the larvae and young of many species of fish were caught in much greater number at night than in the day time in the upper water layer and usually also in the intermediate layer. In order to make a more systematic investigation we took a series of hauls in the course of 24 hours at one single station in the southern Kattegat, the result of which is described in the following chapter.

## II. Serial hauls during 24 hours in the Southern Kattegat on the 20th and 21st of April 1925.

At a Station in the Southern Kattegat we made some systematic experiments in order to notice differences in catch at certain depths in the day time and at night. The central position of the station (No. 3380) was 56° 15′ N. and 11° 53′ E. The investigations were made here within a circle of about 1 mile in diameter, where the depth varied between 25 and 26 metres. The nature of the bottom was muddy sand.

At this station the following investigations were made:

1. Horizontal hauls every second hour with ring-trawl of stramin at two different depths simultaneously. The length of the wire was for the upper trawl 10 metres, for the lower one 40 metres, and the depth of fishing about 4 metres and 16 metres respectively.[1]) The speed was about 1.8 miles per hour. Each haul lasted 30 minutes from the time when the full length of the wire required was out until the moment at which the hauling in of the net began.

2. Vertical hauls with Hensen Net from 10—0 metres, every second hour.

3. Vertical hauls with Hensen Net from bottom to surface, every second hour.

The Ring-trawl is a large bag of stramin fixed in front to an iron ring of 2 m in diameter. The length of the bag is about 7 metres. It is not a closing net, and when this gear is hauled in, it fishes also at a higher level than that where it goes when the main fishing takes place. The stramin used has 56 threads in 100 mm.

[1]) The depth of fishing has been estimated partly according to the angle between the wire and the sea-surface and partly on the basis of a series of experiments we have made to make out the wire length required in order that the ring-trawl shall reach the bottom at a certain depth with a certain speed of the vessel.

**Table 1. Hydrographical observations (on Temperature and Salinity) at St. 3380; 56° 15′ N. lat. 11° 53′ E. long. — 20. and 21. April 1925. —**

| | 20. April | | | | | | 21. April | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Depth m | $12^{35}$ p.m. | $2^{50}$ p.m. | $4^{40}$ p.m. | $6^{40}$ p.m. | $8^{45}$ p.m. | $11^{00}$ p.m. | $0^{45}$ a.m. | $5^{00}$ a.m. | $6^{40}$ a.m. | $9^{00}$ a.m. |
| | | | | Temperature | | | | | | |
| 0 | 6.40 | 6.40 | 6.40 | 6.45 | .. | 6.20 | 6.20 | 6.0 | 6.00 | .. |
| 5 | 6.56 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 10 | 6.16 | .. | .. | 5.58 | 6.06 | 6.00 | 5.80 | 6.0 | 5.73 | 5.78 |
| 12.5 | 6.11 | 6.28 | .. | .. | .. | .. | .. | .. | .. | .. |
| 15 | 5.78 | 5.87 | 5.22 | 5.22 | 5.34 | 5.04 | 4.66 | .. | 4.90 | .. |
| 17.5 | .. | .. | 5.75 | .. | .. | .. | .. | .. | .. | .. |
| 20 | 5.66 | 5.71[1]) | .. | .. | .. | 5.56 | 5.31 | 5.4 | 5.30 | 5.18 |
| 24 | 6.06 | .. | .. | 5.62 | 5.54 | 5.50 | 5.54 | .. | 5.50 | 5.49 |
| | | | | Salinity | | | | | | |
| 0 | 17.81 | 17.8 | .. | 17.8 | .. | 18.0 | 17.8 | .. | 18.0 | .. |
| 5 | 17.8 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 10 | 17.83 | .. | .. | 18.5 | 18.1 | 17.72 | 17.8 | 17.72 | 18.0 | 18.0 |
| 12.5 | 17.86 | 17.83 | .. | .. | .. | .. | .. | .. | .. | .. |
| 15 | 24.34 | 21.22 | 21.9 | 24.4 | 27.3 | 25.99 | 25.3 | .. | 23.3 | .. |
| 17.5 | .. | .. | 31.26 | .. | .. | .. | .. | .. | .. | .. |
| 20 | 32.83 | 32.94[1]) | .. | .. | .. | 32.68 | 33.4 | 32.83 | 33.2 | 32.7 |
| 24 | 33.53 | .. | .. | 33.6 | 33.51 | 33.53 | 33.6 | .. | 33.7 | 33.6 |

[1]) 22 m.

The salinities given with one decimal are determined with hydrometer, the others by titration.

The Hensen Net used was one of the ordinary type made of Müller gaze with 23 strands in 10 mm. The opening of the net was 67 cm in diameter.

The Tables 1 and 2 contain some hydrographical and meteorological observations on the station,

**Table 2. Meteorological observations at St. 3380 (56° 15′ N., 11° 53′ E.) 20. and 21. April 1925.[1])**

| Time | Cover of cloud | Wind (direction from) Scale 0—12 (Beaufort) | Sea (direction from) Scale 0—12 |
|---|---|---|---|
| 12 noon | Sky clear. Cumulus and cirrus near horizont | NW. 2 | NW. 2 |
| 2 p. m. | — | NW. 1 | NW. 1 |
| 4 p. m. | — | W. 1 | NW. $^1/_2$ |
| 6 p. m. | — | No wind | Nearly calm |
| 8 p. m. | — | — | — |
| 10 p. m. | Sky clear. Clouds near horizont | — | — |
| 12 midnight | — | NW. 1 | NW. 1 |
| 2 a. m. | — | NW. 4 | NW. 4 |
| 4 a. m. | Sky covered. Stratus | — | — |
| 6 a. m. | — | — | — |
| 8 a. m. | — | — | — |
| 9.15 a. m. | Sky covered. Stratus. Showers | NNW. 5 | NNW. 4 |

[1]) The sunset occurred at 7.22 p. m. on the 20. of April and the sun-rise at 4.53 a. m. on the 21. of April. It was new moon on the 23. of April at 3.28 a. m.

**Table 3. Number of Young Fishes caught with Ring-trawl in the upper layer at about 4 metres depths at St. 3380 in the southern Kattegat, 20.—21. April 1925.**

Duration of hauls: 30 minutes.

| Haul No. | | | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour shot | | | 12 p.m. | 2 p.m. | 4 p.m. | 6 p.m. | 8 p.m. | 10 p.m. | 12 midnight | 2 a.m. | 4 a.m. | 6 a.m. | 8 a.m. | 9[15] a.m.[1] |
| Species | Length mm | Stage of development | | | | | | | | | | | | |
| Cottus scorpius | 8—19 | larvae | .. | .. | .. | 1 | .. | .. | 2 | .. | 1 | .. | .. | .. |
| — lilljeborgi | 4—8 | — | .. | .. | .. | .. | 1 | .. | 2 | .. | .. | .. | .. | .. |
| Agonus cataphractus | 13—17 | transition stage | .. | .. | .. | .. | 1 | 2 | 1 | .. | .. | .. | .. | .. |
| Liparis sp. | 6—11 | larvae | .. | .. | .. | 1 | .. | 4 | 11 | 5 | 1 | .. | .. | .. |
| — | 13 | transition stage (coloured) | .. | .. | .. | .. | .. | 1 | .. | 1 | .. | .. | .. | .. |
| Gobius microps | 26—35 | young fish after metamorph. | .. | .. | .. | .. | .. | .. | 2 | 2 | .. | .. | .. | .. |
| — scorpioides | 13—17 | — | .. | .. | .. | .. | .. | .. | 1 | 4 | .. | .. | .. | .. |
| Lumpenus lampetriformis | 20—40 | larvae | .. | .. | .. | 1 | .. | .. | .. | 1 | .. | .. | .. | .. |
| Centronotus gunellus | 16—33 | — | .. | .. | .. | .. | .. | 2 | 2 | 4 | .. | .. | .. | .. |
| Chirolophus ascanii | 28 | — | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| Gadus callarias | 5—9 | — | 6 | 10 | 38 | 43 | 3 | 2 | 2 | 5 | .. | 13 | 6 | 4 |
| — — | 10—19 | — | 4 | 4 | 9 | 8 | 14 | 3 | 24 | 10 | 3 | 6 | 3 | 1 |
| — — | 20—29 | — | 1 | 2 | 1 | 3 | 3 | 1 | .. | 1 | 2 | 1 | 1 | .. |
| — — | 30—31 | — | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Ammodytes sp. | 10—19 | — | .. | .. | 1 | .. | 2 | .. | 3 | 2 | 3 | 1 | .. | .. |
| — | 20—29 | — | .. | .. | .. | .. | .. | 3 | 7 | 6 | 3 | 1 | 7 | 1 |
| — | 30—39 | — | .. | .. | .. | .. | .. | 1 | 10 | 6 | 1 | 1 | .. | .. |
| — | 40—43 | — | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. |
| Drepanopsetta platessoides | 6—11 | — | .. | 3 | 25 | 12 | .. | 4 | 4 | 3 | .. | .. | .. | 1 |
| Pleuronectes platessa | 14 | — | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. |
| — flesus | 6—7 | — | .. | .. | 2 | .. | 1 | 1 | 1 | .. | .. | .. | .. | .. |
| Clupea harengus | 6—9 | — (yolk sac) | .. | .. | 2 | 1 | 1 | .. | .. | 2 | 2 | 2 | .. | .. |
| — — | 10—18 | — | 2 | 1 | 8 | 38 | 8 | 9 | 87 | 92 | 6 | 27 | 7 | 6 |
| — — | 20—42 | — | .. | .. | .. | .. | .. | .. | 5 | 5 | .. | .. | .. | .. |
| Anguilla vulgaris | 68 | elvers | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| Number of species | .. | .. | 2 | 3 | 5 | 6 | 6 | 8 | 14 | 10 | 5 | 3 | 3 | 4 |

[1]) Catch in Fig. 1—4 displaced to 10 a.m.

and the Tables 3 and 4 denote number of larvae or young of various fishes caught per 30 minutes' haul in the upper and intermediate layers, respectively.

As will be seen from Tables 3 and 4, the hauls show a maximum for most species at night, with a minimum in the forenoon and early afternoon. This applies to such species as *Cottus scorpius, Agonus cataphractus, Liparis* sp. *Gobius microps, Gobius scorpioides, Lumpenus lampetriformis, Centronotus gunellus, Ammodytes tobianus, Pleuronectes platessa, Pl. flesus* and *Clupea harengus.* In the case of some species, such as Cottus lilljeborgi, Anarrhichas lupus, Chirolophus ascanii and Anguilla vulgaris, the hauls yielded only a single specimen, or at most a very few; these were, however, practically all taken at night. Only two species: Gadus callarias and Drepanopsetta platessoides appear to form an exception to the general rule. These species show two maxima: one in the afternoon (abt. 4—6 p.m.) and another about midnight. It is doubtful, however, whether any general conclusions can be drawn from these few observations. It should be borne in mind that the larvæ move more or less in shoals, and this fact may affect the typical aspect of things at individual stations. (See chap. VIII).

A survey of the number of species of fish taken at different times during the twentyfour hours shows that in this respect also there is a maximum at night, with a minimum in the forenoon and early afternoon (Fig. 1).

**Table 4. Number of Young Fishes caught with Ring-trawl in the intermediate layer at about 16 metres depth at St. 3380 in the southern Kattegat 20.—21. April 1925.**

Durations of hauls: 30 minutes.

| Haul No. | | | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour shot | | | 12 noon | 2 p.m. | 4 p.m. | 6 p.m. | 8 p.m. | 10 p.m. | 12 midnight | 2 a.m. | 4 a.m. | 6 a.m. | 8 a.m. | 9[15] a.m. |
| Species | Length mm | Stage of development | | | | | | | | | | | | |
| Cottus scorpius | 12—17 | larvae | .. | .. | .. | .. | .. | .. | 3 | .. | .. | .. | .. | .. |
| Agonus cataphractus | 15 | transition stage | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| Liparis sp. | 6—11 | larvae | .. | .. | .. | 1 | .. | 1 | 3 | 7 | 1 | .. | .. | .. |
| Gobius microps | 27—30 | young fish | .. | .. | .. | .. | .. | .. | 1 | 1 | .. | .. | .. | .. |
| — scorpioides | 14—15 | — | .. | .. | .. | .. | .. | .. | 3 | 1 | .. | .. | .. | .. |
| Lumpenus lampetriformis | 26—41 | larvae | .. | .. | .. | 1 | .. | .. | 1 | 1 | .. | .. | .. | .. |
| Anarrhichas lupus | 43—47 | transition stage | .. | .. | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. |
| Centronotus gunellus | 28—33 | larvae | .. | .. | .. | .. | .. | 1 | .. | 7 | .. | .. | .. | .. |
| — — | 50 | young fish | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| Gadus callarias | 4—9 | larvae | 14 | 38 | 4 | 10 | 4 | 1 | 3 | .. | 1 | 7 | 3 | .. |
| — — | 10—19 | — | 2 | 7 | 5 | 16 | 6 | 3 | 8 | 10 | 5 | 9 | 2 | .. |
| — — | 20—26 | — | 1 | .. | 1 | 1 | .. | .. | 2 | 1 | 1 | 1 | .. | .. |
| Onos cimbrius | 32 | — | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. |
| Ammodytes sp. | 10—19 | — | .. | .. | .. | .. | .. | 2 | 3 | 6 | 2 | 1 | .. | .. |
| — | 20—29 | — | .. | .. | .. | .. | 1 | 1 | 3 | 12 | 9 | 3 | .. | .. |
| — | 30—39 | — | .. | .. | .. | .. | .. | .. | 5 | 2 | 1 | .. | .. | .. |
| — | 40—45 | — | .. | .. | .. | .. | .. | .. | .. | .. | 2 | .. | .. | .. |
| Drepanopsetta platessoides | 6—11 | — | 2 | 6 | 5 | 2 | 2 | 1 | 5 | 2 | 1 | .. | .. | .. |
| Pleuronectes platessa | 9—15 | — | .. | .. | 1 | 1 | .. | .. | 2 | .. | .. | .. | .. | .. |
| — flesus | 5—10 | — | 1 | .. | .. | 1 | 1 | .. | 2 | .. | .. | .. | .. | .. |
| Clupea harengus | 6—9 | — | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| — — | 10—17 | — | 8 | 7 | 5 | 6 | 10 | 2 | 48 | 51 | 8 | 24 | 10 | 6 |
| — — | 21—34 | — | .. | .. | .. | .. | .. | .. | 6 | 5 | 1 | .. | .. | .. |
| Number of species | .. | .. | 4 | 3 | 4 | 7 | 5 | 7 | 13 | 9 | 5 | 4 | 2 | 1 |

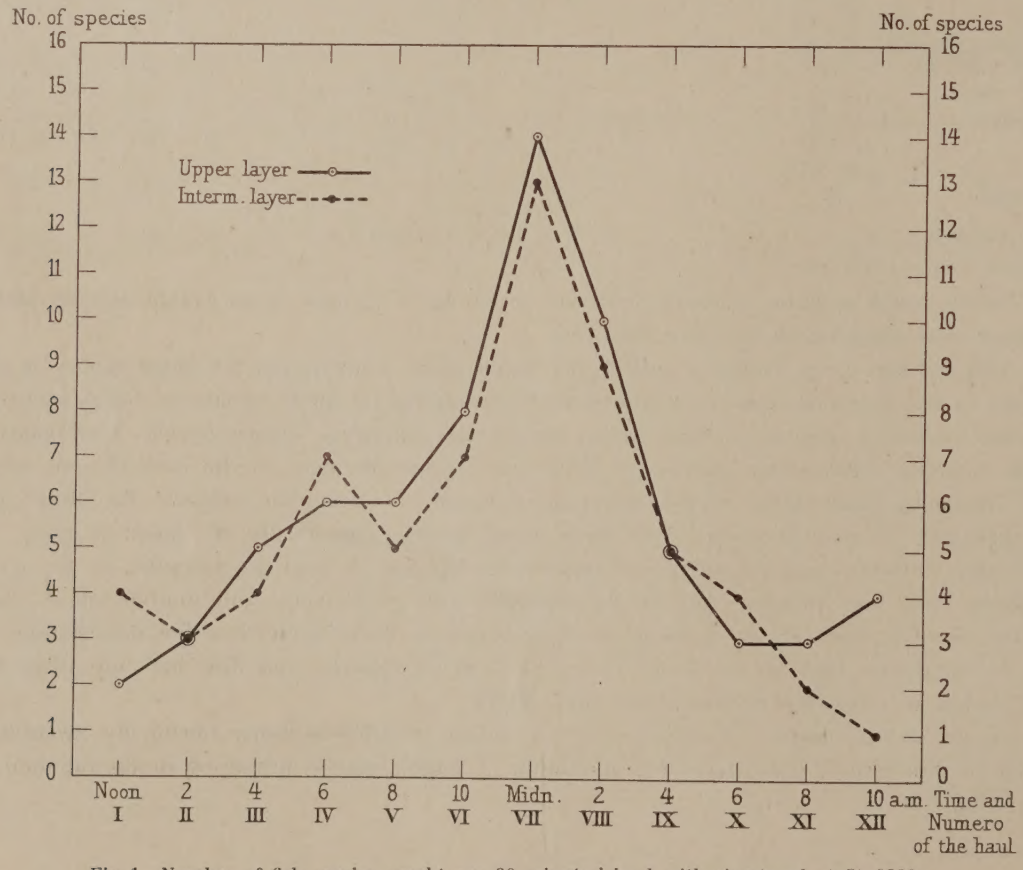


Fig. 1.. Number of fish species caught per 30 minutes' haul with ring-trawl at St. 3380 in the southern Kattegat. April 20.—21. 1925.

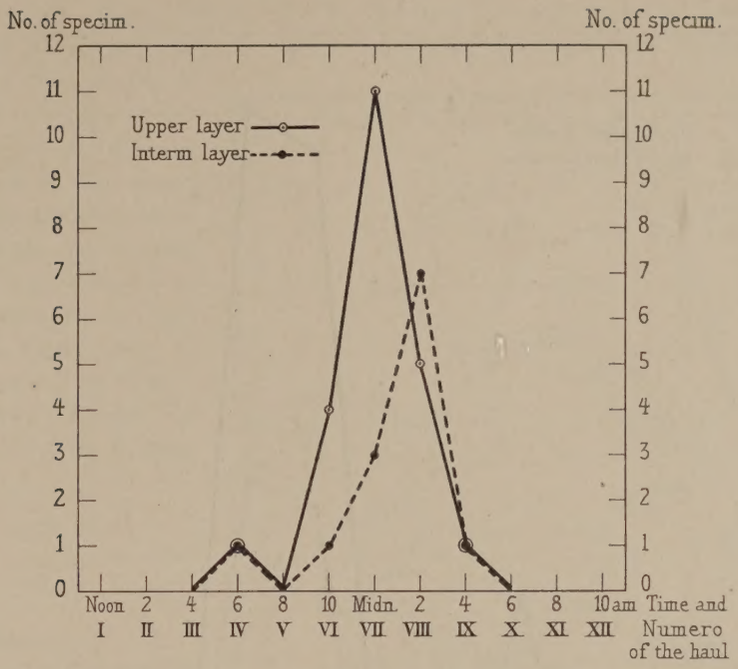
No. of specim.
No. of specim.
Upper layer
Interm layer
Noon 2 4 6 8 10 Midn. 2 4 6 8 10am Time and
I II III IV V VI VII VIII IX X XI XII Numero
of the haul

Fig. 2. Number of larvae of *Liparis* caught per 30 minutes' haul with ring-trawl at St. 3380 in the southern Kattegat. April 20.—21. 1925.

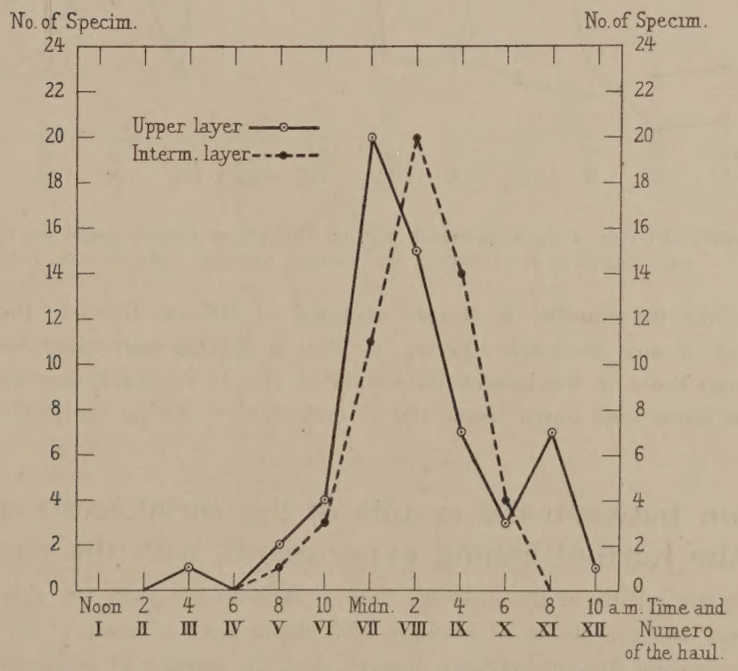
No. of Specim.
No. of Specim.
Upper layer
Interm. layer
Noon 2 4 6 8 10 Midn. 2 4 6 8 10 a.m. Time and
I II III IV V VI VII VIII IX X XI XII Numero
of the haul.

Fig. 3. Number of larvae of Sand-eel *(Ammodytes)* caught per 30 minutes' haul with ring-trawl at St. 3380 in the southern Kattegat. April 20.—21. 1925.

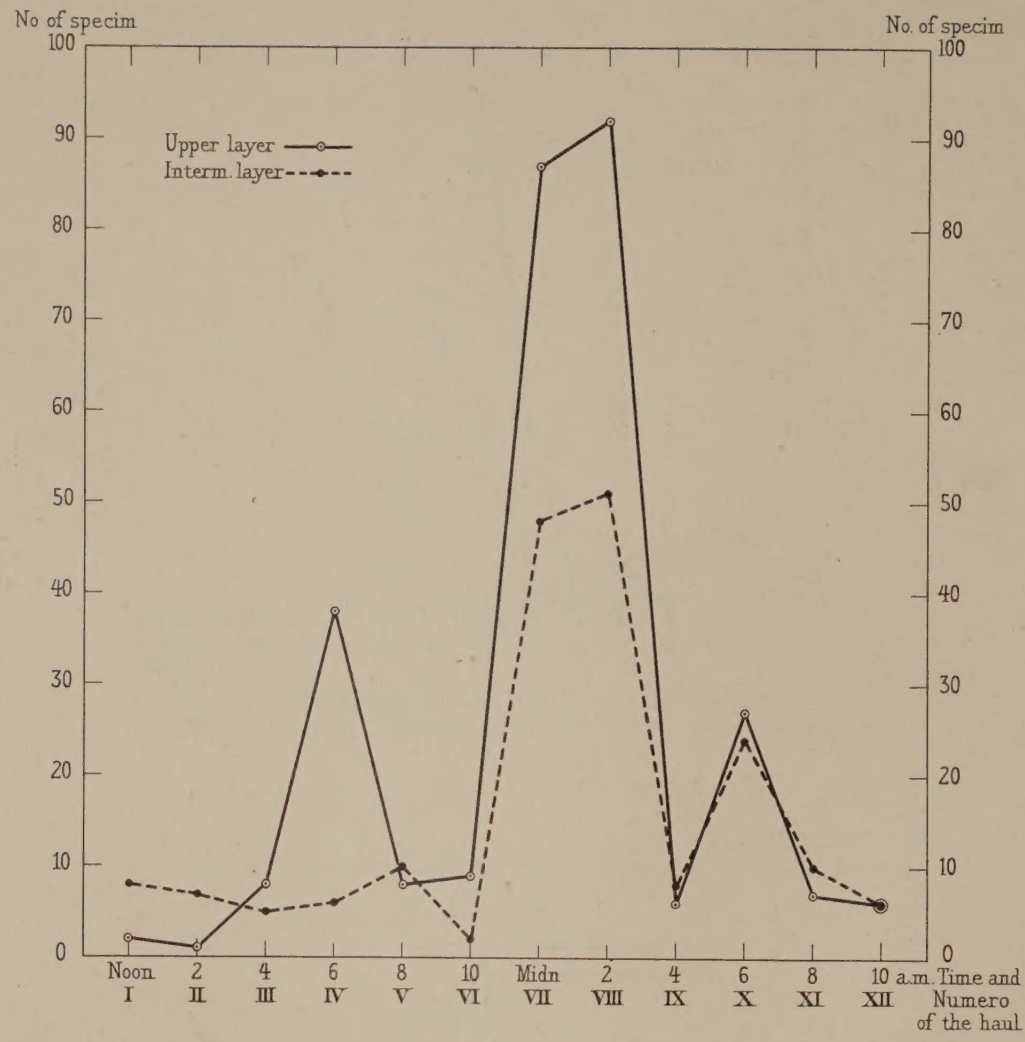


Fig. 4. Number of larvae of winter spawning herrings (10—18 mm length) caught per 30 minutes' haul with ring-trawl at St. 3380 in the southern Kattegat. April 20.—21. 1925.

Whether we take the number of species captured at different times of the day and night, or the number of specimens of any particular species, we find a striking agreement between the hauls in the upper water layer and those in the intermediate layer at abt. 16 m depth (see Figs. 1—4). This suggests that majority of the larvæ kept down below the 16 metres' level during the day.

## III. Comparison between the results of the serial hauls during 24 hours, and the normal fishing experiments with the ring-trawl.

Table 5 gives the results of the ordinary fishing experiments with the ring-trawl in April 1925 in the Kattegat, Belt Sea and the Baltic at stations with depth over 15 metres. We will here compare the results of these experiments for the various species, and the results of serial experiments at the single station in the southern Kattegat, as far as hauls of fish larvæ and young fish are concerned. As regards the ordinary fishing experiments, we divide our material into two parts, viz: day hauls between 6 a.m.

and 6 p.m. and night hauls between 9 p.m. and 3 a.m. Hauls between 3 and 6 a.m. and between 6 and 9 p.m. were only made at very few stations, and we may disregard them here. A survey of the positions of the various stations is given in Fig. 5.

In the ordinary fishing experiments with the ring-trawl, we will now consider the hauls made in the upper water layers. These we have reckoned, in the case of the Kattegat and the Belt Sea, as comprising the depths from 0 to 8 metres (up to 20 metres of wire out), and in the case of the Baltic, down to abt. 12 metres depth (up to 30 metres of wire out). The numbers of stations for the upper water layers were as follows:

| | Kattegat (incl. Sound) | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls ... | 8 | 5 | 3 | 16 | Stns. |
| Night hauls .. | 3 | 2 | 2 | 7 | — |

### Cottus scorpius L.

In the serial hauls at St. 3380 in the southern Kattegat, some few specimens were taken between 6 p.m. and 4 a.m. but none between 6 a.m. and 6 p.m. In the ordinary fishing experiments with the ring-trawl, the average yield per hour for day and night hauls was as follows:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls .. | 1 | 1 | 1 | 1 | Spec. |
| Night hauls . | 1 | 4 | 8 | 4 | — |

The captures were on the whole but small; there is, however, good agreement between the results.

Fig. 5. Stations where ring-trawl was used at depths above 15 m, during "Dana"s cruise in April of 1925.
The circle over the line denotes hauls in the upper layers (0—8 à 12 metres). The circle under the line denotes hauls in the intermediate or lower layer.

### Cottus bubalis Euphrasén and Cottus lilljeborgi Collett.[1])

Of these closely related species, only very few specimens were taken in our experiments of April 1925. Serial hauls in the surface layer at St. 3380 in the southern Kattegat yielded 3 specimens of C. lilljeborgi between 8 p.m. and 12 midnight; none were taken in the day hauls. The ordinary fishing experiments with the ring-trawl in April 1925 yielded no specimens of this species, but a few of Cottus bubalis. The average per hour was as follows:

[1]) The larvæ of this species were determined by A. Bruun (see A. Bruun 1925).

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 0.1 | 0 | 0 | 0.1 | specimens |
| Night hauls | 0 | 2 | 1 | 1 | — |

**Agonus cataphractus L.**

Serial hauls at St. 3380 yielded some few postlarval stages of this species between 8 p.m. and 12 midnight, but none during the day. Ordinary fishing experiments with the ring-trawl gave the following average per hour:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 1 | 0 | 1 | 0.4 | specimens |
| Night hauls | 1 | 3 | 0 | 2 | — |

**Liparis sp.**[1])

The serial hauls at St. 3380 in the southern Kattegat showed a pronounced maximum at night between 10 p.m. and 2 a.m., and a minimum from 6 a.m. to 4 p.m. (see Fig. 2). Ordinary fishing experiments with the ring-trawl gave the following averages per hour:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 19 | 0 | 1 | 10 | specimens |
| Night hauls | 10 | 12 | 34 | 17 | — |

It will be noticed that the larvæ of this species were occasionally more frequent in the day hauls than at night; the total result, however, gives the greatest yield in night hauls.

**Gobius minutus** Pallas, **Gobius pictus** Malm and **Gobius microps** Krøyer.

Young specimens of Gobius minutus, pictus, and microps were taken in the serial hauls in the southern Kattegat only at night, in the ordinary fishing experiments with the ring-trawl the average per hour was as follows:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 0 | 0 | 0 | 0 | specimens |
| Night hauls | 0 | 11 | 2 | 4 | — |

There is thus a nice agreement between the results. It is nevertheless quite possible that specimens of these species may be taken in day hauls.

**Gobius scorpioides** Collett.

Serial hauls in the southern Kattegat, upper and intermediate layers, yielded 9 metamorphosed specimens of the handsome little Gobius scorpioides, all taken in hauls between 12 midnight and 2 a.m. Ordinary fishing experiments with the ring-trawl gave the following averages per hour at the surface:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 0 | 0 | 0 | 0 | specimens |
| Night hauls | 16 | 0 | 0 | 7 | — |

This little Gobius species evidently keeps to the sea floor during the day. In the intermediate and lower water layers also it has only been taken pelagically during the night. Fig. 6 shows the no. of specimens of this species taken in night hauls at the different stations.

**Lumpenus lampetriformis** Walbaum.

Serial hauls in the southern Kattegat yielded some few larvæ of this species between 6 p.m. and 2 a.m.; none in the daytime. Ordinary fishing experiments with the ring-trawl gave the following averages per hour:

[1]) The species here concerned would be *L. liparis* L. and *L. montagui* Donovan.

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls ..... | 1 | 0 | 0 | 0.4 | specimens |
| Night hauls ..... | 2 | 19 | 0 | 6 | — |

This species is thus also chiefly taken in night hauls in the upper water layers.

**Centronotus gunellus** L.

Serial hauls at St. 3380 in the southern Kattegat, both in the surface and intermediate water layers, yielded 8 larvæ of this species, all taken at night, between 10 p.m. and 2 a.m. Ordinary fishing experiments with the ring-trawl in the upper water layers gave the following averages per hour:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls ... | 1 | 0 | 0 | 0.5 | specimens |
| Night hauls.. | 3 | 19 | 9 | 11 | — |

The results of the serial hauls thus agree very nicely with those of the ordinary fishing experiments.

**Gadus callarias** L.

In the serial hauls at St. 3380 in the southern Kattegat we did not find in this case, as with most of the other species, any pronounced maximum in the numbers of larvæ at night. The greatest numbers captured in the upper water layers were taken between 4 and 6 p.m; and a less pronounced maximum was observed again at midnight. (Fig. 11). The ordinary fishing experiments with the ring-trawl however, showed that on the average, more larvæ were taken at night than by day, but the difference here is not so marked as in the case of most of the other species. The average per hour was as follows:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls... | 47 | 20 | 1 | 30 | specimens |
| Night hauls.. | 73 | 119 | 25 | 72 | — |

The brackish water in the Baltic proper yielded on the average fewer cod larvæ per fishing unit than the Kattegat or the Belt Sea.

Fig. 6. Number of specimens of *Gobius scorpioides* caught per 30 minutes' haul with ring-trawl during the night. April 1925. No catch occurred in the day-hauls, nor in the morning and evening-hauls (comp. Fig. 5).

**Ammodytes lancea** Cuvier & **A. lanceolatus** Lesauvage.

In the case of this genus, serial hauls in the southern Kattegat presented the typical picture: large captures of larvæ in the upper water layers were made only at night. Ordinary fishing experiments with the ring-trawl revealed the same phenomenon, as will be seen from the table below showing averages per hour:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 9 | 5 | 5 | 7 | specimens |
| Night hauls | 20 | 2211 | 1579 | 1091 | — |

The night hauls here thus show a quite extraordinary preponderance over the daytime yield (see Fig. 7).

At stations where very large numbers were taken at night in the surface layers, the numbers taken in the intermediate layers were considerably less. At St. 3378 in the Arkona Basin, in the upper layer (30 m. w.) 1571 larvæ and young fish from 13 to 91 mm were taken, whereas in the intermediate layer none were taken at all (see Table 5). The lengths of 485 Ammodytes measured from St. 3378 were as follows:

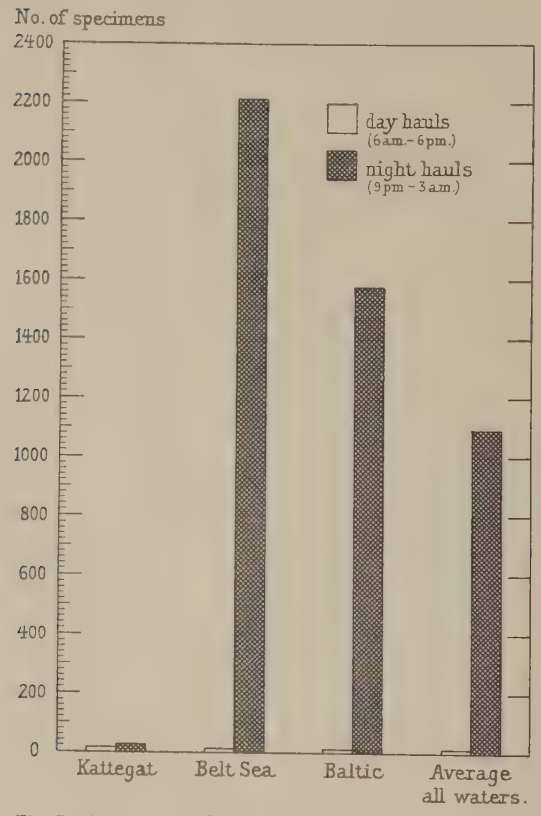


Fig. 7. Average number of larvae and young of *Ammodytes* caught per hour with ring-trawl in day-hauls and in night-hauls in the upper layer of the Kattegat, Belt Sea and western Baltic. April 1925.

| Length cm. | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 | 5.5 | 6 | 6.5 — 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of specimens | 22 | 52 | 116 | 77 | 52 | 67 | 38 | 26 | 22 | 8 | 4 — 1 |

**Drepanopsetta platessoides** O. Fabricius.

Serial hauls at St. 3380 in the southern Kattegat yielded approximately the same number of larvæ at night as during the day. Ordinary fishing experiments with the ring-trawl gave the following per hour in the upper water layers:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 2 | 0 | 0 | 0.8 | specimens |
| Night hauls | 6 | 1 | 0 | 3 | — |

The material from the ordinary fishing experiments is in this case but slight. As far as it goes, it suggests a heavier yield at night than by day.

**Pleuronectes platessa** L., **Pl. flesus** L. & **Pl. limanda** L.

In the serial hauls at St. 3380 in the southern Kattegat, the captures were so small and scattered as to afford no clear impression of whether the larvæ were or were not present in greater numbers in the upper water layers by night. Ordinary fishing experiments with the ring-trawl gave captures per hour as follows:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 2 | 0 | 0 | 0.8 | specimens |
| Night hauls | 8 | 1 | 0 | 3 | — |

We find then, in the case of these Pleuronectes species also, a heavier yield at night than during the day.

**Clupea harengus** L.

Save for a very few newly hatched larvæ of the spring herring, the larvæ here considered fall into two size-groups, originating respectively from winter-spawning and from autumn-spawning herring. The larvæ of the winter-spawning fish measured from abt. 8—19 mm; those of the autumn spawning herring 20—43 mm.

In the serial hauls from the southern Kattegat, most of the larvæ of winter herring were taken between 12 and 2 o'clock at night. Captures during the remainder of the twentyfour hours were somewhat irregular (see Fig. 4). Ordinary fishing experiments with the ring-trawl in the upper water layers gave the following averages per hour:

| | Kattegat | Belt Sea | Baltic | Total | |
|---|---|---|---|---|---|
| Day hauls | 17 | 0.4 | 0 | 4 | specimens |
| Night hauls | 37 | 19 | 1 | 22 | — |

It seems then to be a phenomenon of common occurrence that herring larvæ of abt. 8—19 mm. should be taken in the upper water layers in far greater numbers at night than during the day.

Larvæ of autumn-spawning herring (20—43 mm. length).

In the serial hauls from the surface layer in the southern Kattegat, 20—21 April 1925, larvæ of autumn-spawning herring were only taken during the night. Ordinary fishing experiment in April 1925 gave the following captures per hour for the surface layers:

| | Kattegat | Belt Sea | Baltic | Total |
|---|---|---|---|---|
| Day hauls | 0 | 0 | 0 | 0 specimens |
| Night hauls | 11 | 79 | 19 | 33 — |

The results of the serial experiments are thus in complete agreement with those of the ordinary fishing experiments.

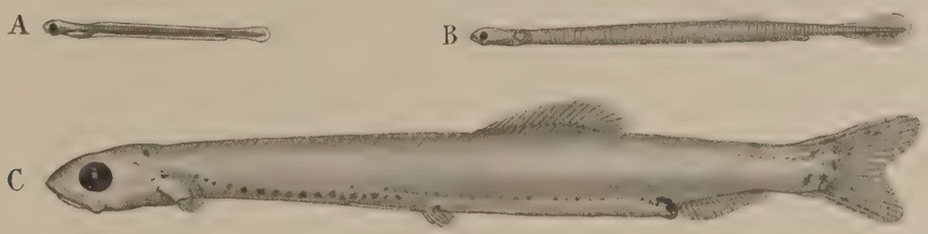


Fig. 8. Shape of herring larvae of different length. Kattegat medio April 1925.
A) Larva of spring-spawning herring of 8,5 mm length.
B) — - winter-spawning herring of 16 mm length.
C) — - autumn-spawning herring of 32 mm length.
(Drawn by Fru Bodil Strubberg).

**Anguilla vulgaris** Turton.

Serial hauls in the surface layer of the southern Kattegat on the 20—21 April 1925 yielded only a single elver, which was taken at 12 midnight. Ordinary fishing experiments with the ring-trawl in April 1925 gave the following averages per hour:

| | Kattegat | Belt Sea | Baltic | Total |
|---|---|---|---|---|
| Day hauls | 0 | 0 | 0 | 0 specimens |
| Night hauls | 3 | 0 | 0 | 1 — |

The captures of elvers were thus very small, both for the serial hauls in the southern Kattegat and for the ordinary fishing experiments with ring-trawl in April 1925; they agree however, with the results of previous fishing experiments made by the present writer in the North Sea, Skagerak and Kattegat (A. C. Johansen 1905).

It will be seen that for all species observed the average catch of specimens in the upper layers has been larger in the night-hauls than in the day-hauls.[1]) (Fig. 9). In accordance with this fact we notice that also the average number of fish species caught per haul was larger in the night-hauls than in the day-hauls. The average number of fish species caught per hour with ring-trawl in the Kattegat, Belt Sea and western Baltic was as follows:

day hauls: 3 species
night hauls: 10 —

The investigations show that if we compare the results of fishing experiments with ring-trawl in the upper layers from different areas, or from same area at different times, it is of importance to take into consideration at what time of the day the hauls are made.

[1]) A few species of which only 1—3 specimens were captured, are not considered here.

**Table 5. List of stations with Ring-Trawl and Young-Fish-Trawl[1]) in April of 1925. Depth more**

| Station No. | Date (1925) | Locality | Central Position N. | Central Position E. | Depth m | Time of fishing | Length of wire out. m | Approximate fishing depth | Temperature °C surface | Temperature °C fishing depth | Salinity ‰ surface | Salinity ‰ fishing depth | Cottus scorpius | Cottus bubalis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3341 | April 7 | Hertha's Flak | 57°38′ | 10°52′ | 19 | $9^{00}$ p.m. to $9^{30}$ p.m. | 20 | 8 | 4.1 | ca. 4.1 | 22.0 | ca.23.0 | .. | .. |
| 3342 | — 8 | Kummel Bank | 57°28′ | 11°24′ | 22 | $0^{10}$ a.m. - $0^{40}$ a.m. | 40 | 16 | 4.4 | - 4.0 | 20.1 | - 32.5 | .. | .. |
| 3343 | — — | E. of Kobbergrund | 57°09′ | 11°25′ | 70 | $3^{40}$ — - $5^{40}$ — | 50 | 20 | 3.2 | - 4.6 | 18.0 | - 33.3 | 2 | .. |
| — | — — | — - — | — | — | — | $6^{50}$ — - $7^{20}$ — | 20 | 8 | — | - 3.8 | — | - 24.0 | 1 | 1 |
| 3344 | — — | Groves Flak | 57°07′ | 11°43′ | 25 | $8^{50}$ — - $9^{20}$ — | 40 | 16 | 3.8 | - 4.3 | 17.7 | - 31.0 | .. | .. |
| 3345 | — — | W. of Lille Middelgrund | 56°58′ | 11°45′ | 62 | $11^{20}$ — - $11^{50}$ — | 70 | 28 | 4.1 | - 5.1 | 17.6 | - 33.7 | 1 | .. |
| 3347 | — — | E. of Anholt Knob light-vessel | 56°45.5′ | 11°54.5′ | 45 | $5^{10}$ p.m. - $5^{40}$ p.m. | 70 | 28 | 4.8 | - 5.0 | 17.9 | - 33.3 | .. | .. |
| 3349 | — — | E. of Store Middelgrund | 56°33.5′ | 12°13′ | 48 | $9^{10}$ — - $10^{10}$ — | 70 | 28 | 3.9 | - 5.3 | 18.0 | - 33.0 | 1 | 2 |
| 3350 | — 14 | S. of Hveen | 55°51.5′ | 12°45′ | 35 | $10^{30}$ a.m. - $10^{45}$ a.m. | 10 | 4 | 6.0 | - 5.7 | 8.3 | - 8.5 | .. | .. |
| — | — — | — - — | — | — | — | $10^{55}$ — - $11^{25}$ — | 50 | 20 | — | - 5.6 | — | - 32.3 | 7 | .. |
| 3351 | — — | S.W. of Viken | 56°07′ | 12°32′ | 27 | $1^{40}$ p.m. - $2^{10}$ p.m. | 10 | 4 | 6.0 | - 5.5 | 8.2 | - 12.5 | 1 | .. |
| — | — — | — - — | — | — | — | — — | 50 | 20 | — | - 5.5 | — | - 31.0 | 1 | 1 |
| 3352 | — — | E. of Lysegrund | 56°18′ | 12°03′ | 32 | $5^{50}$ p.m. - $6^{20}$ p.m. | 10 | 4 | 6.6 | - 5.5 | 15.2 | - 16.5 | .. | 1 |
| — | — — | — - — | — | — | — | — — | 50 | 20 | — | - 5.6 | — | - 33.7 | 1 | 1 |
| 3353 | — — | S. of Anholt | 56°30.5′ | 11°35′ | 31 | $8^{45}$ p.m. - $9^{15}$ p.m. | 10 | 4 | 6.8 | - 6.0 | 16.2 | - 17.0 | .. | .. |
| — | — — | — - — | — | — | — | — — | 50 | 20 | — | - 5.1 | — | - 32.1 | .. | .. |
| 3354 | — — | S.W. of Anholt Harbour | 56°37′ | 11°22′ | 18 | $11^{15}$ p.m. - $11^{45}$ p.m. | 10 | 4 | 5.6 | - 5.2 | 15.4 | - 16.0 | 2 | .. |
| — | — — | — - — | — | — | — | — — | 30 | 12 | — | - 4.6 | — | - 21.0 | 1 | 2 |
| 3355 | — 15 | N. by E. of Læsø Rende light-vessel | 57°14′ | 10°42′ | 20 | $5^{50}$ a.m. - $6^{20}$ a.m. | 10 | 4 | 5.7 | - 5.5 | 18.9 | - 20.0 | .. | .. |
| — | — — | — - — | — | — | — | — — | 40 | 16 | — | - 5.0 | — | - 33.0 | .. | .. |
| 3361 | — 16 | S.E. of Fornæs | 56°22′ | 11°17′ | 36 | $11^{55}$ a.m. - $12^{25}$ p.m. | 10 | 4 | 5.6 | - 5.6 | 16.2 | - 16.3 | .. | .. |
| — | — — | — - — | — | — | — | — — | 50 | 20 | — | - 5.5 | — | - 32.6 | .. | 1 |
| 3362 | — — | S.W. of Schultz' Grund light-vessel | 56°06′ | 11°09′ | 34 | $2^{25}$ p.m. - $2^{55}$ p.m. | 20 | 8 | 6.1 | - 5.4 | 15.5 | - 17.0 | .. | .. |
| — | — — | — - — | — | — | — | — — | 60 | 24 | — | - 5.4 | — | - 32.5 | 1 | .. |
| 3363 | — — | S.E. of Hjelm | 56°06′ | 10°55′ | 31 | $4^{10}$ p.m. - $4^{40}$ p.m. | 20 | 8 | 6.0 | - 5.2 | 14.3 | - 17.5 | .. | .. |
| — | — — | — - — | — | — | — | — — | 60 | 24 | — | - 5.6 | — | - 31.0 | .. | .. |
| 3364 | — — | S. of Hatter Rev | 55°52′ | 10°49′ | 40 | $6^{45}$ p.m. - $7^{15}$ p.m. | 20 | 8 | 6.0 | - 5.9 | 13.8 | - 14.0 | .. | .. |
| — | — — | — - — | — | — | — | — — | 60 | 24 | — | - 5.5 | — | - 31.0 | .. | .. |
| 3365 | — — | S.E. of Romsø | 55°30′ | 10°52′ | 30 | $10^{15}$ — - $10^{45}$ p.m. | 10 | 4 | 6.0 | - 5.9 | 12.0 | - 14.0 | 3 | 3 |
| — | — — | — - — | — | — | — | — — | 50 | 20 | — | - 5.5 | — | - 31.0 | 3 | .. |
| 3368 | — 17 | N.N.W. of Omö light | 55°12′ | 11°05.5′ | 32 | $10^{00}$ a.m. - $10^{30}$ a.m. | 10 | 4 | 6.0 | - 6.0 | 13.0 | - 14.5 | .. | .. |
| — | — — | — - — | — | — | — | — — | 40 | 16 | — | - 6.0 | — | - 24.5 | .. | .. |
| 3369 | — — | S.E. of Spodsbjerg light | 54°55′ | 10°52′ | 29 | $0^{15}$ p.m. - $0^{45}$ p.m. | 10 | 4 | 6.2 | - 6.1 | 12.4 | - 12.6 | 1 | .. |
| — | — — | — - — | — | — | — | — — | 40 | 16 | — | - 5.7 | — | - 23.0 | 1 | .. |
| 3370 | — — | S.W. of Langeland | 54°41′ | 10°28′ | 30 | $3^{45}$ p.m. - $4^{15}$ p.m. | 10 | 4 | 5.6 | - 5.7 | 14.2 | - 14.2 | 1 | .. |
| — | — — | — - — | — | — | — | — — | 40 | 16 | — | - 5.5 | — | - 15.0 | .. | .. |
| 3371 | — — | Fehmern Belt | 54°36′ | 11°04′ | 27 | $6^{45}$ p.m. - $7^{15}$ p.m. | 20 | 8 | 6.2 | - 5.6 | 11.6 | - 13.5 | .. | .. |
| — | — — | — | — | — | — | — — | 50 | 20 | — | - 5.4 | — | - 18.1 | 1 | 1 |
| 3372 | — — | S.E. of Staberhuk | 54°22′ | 11°23′ | 23 | $9^{50}$ p.m. - $10^{20}$ p.m. | 10 | 4 | 5.6 | - 5.5 | 10.2 | - 10.2 | 1 | .. |
| — | — — | — - — | — | — | — | — — | 40 | 16 | — | - 5.4 | — | - 12.0 | .. | .. |
| 3373 | — 18 | E.S.E. of Staberhuk | 54°22′ | 11°41′ | 25 | $6^{15}$ a.m. - $6^{45}$ a.m. | 20 | 8 | 5.8 | - 5.6 | 10.5 | - 10.6 | .. | .. |
| — | — — | — - — | — | — | — | — — | 50 | 20 | — | - 5.0 | — | - 19.3 | .. | .. |
| 3374 | — — | Kadetrende | 54°25′ | 12°10′ | 21 | $9^{30}$ a.m. - $10^{00}$ a.m. | 10 | 4 | 6.2 | - 6.2 | 10.9 | - 11.0 | .. | .. |
| — | — — | — | — | — | — | — — | 40 | 16 | — | - 5.4 | — | - 14.0 | .. | .. |
| 3375 | — — | E. of Gedser | 54°34.5′ | 12°17′ | 25 | $11^{50}$ a.m. - $12^{20}$ p.m. | 20 | 8 | 5.6 | - 5.4 | 9.3 | - 11.5 | 1 | .. |
| — | — — | — - — | — | — | — | — — | 50 | 20 | — | - 4.7 | — | - 14.4 | .. | .. |
| 3376 | — — | S.E. of Hestehaven | 54°47′ | 12°20′ | 23 | $2^{25}$ p.m. - $2^{55}$ p.m. | 20 | 8 | 5.4 | - 5.4 | 8.5 | - 8.5 | 1 | .. |
| — | — — | — - — | — | — | — | — — | 50 | 20 | — | - 4.7 | — | - 16.2 | .. | .. |
| 3377 | — — | Möen's Deep | 54°54′ | 12°32.5′ | 27 | $5^{10}$ p.m. - $5^{40}$ p.m. | 20 | 8 | 5.4 | - 5.2 | 8.3 | - 8.1 | .. | .. |
| — | — — | — | — | — | — | — — | 50 | 20 | — | - 4.7 | — | - 9.7 | .. | .. |
| 3378 | — — | N.N.W. of Arkona | 54°54.5′ | 13°09.5′ | 44 | $8^{45}$ p.m. - $9^{15}$ p.m. | 30 | 12 | 5.0 | - 4.8 | 8.1 | - 8.1 | 7 | 1 |
| — | — — | — - — | — | — | — | — — | 90 | 36 | — | - 4.0 | — | - 10.4 | 13 | .. |
| 3379 | — 19 | S.E. of Stevns Light | 55°09′ | 12°40′ | 30 | $1^{50}$ a.m. - $2^{20}$ a.m. | 30 | 12 | 4.6 | 4.8 | 7.8 | 7.9 | 1 | .. |
| — | — — | — - — | — | — | — | — — | 60 | 24 | — | 5.0 | — | 8.1 | .. | 1 |
| 3381 | — 21 | N. of Hveen | 55°57′ | 12°42′ | 27 | $5^{15}$ p.m. - $5^{45}$ p.m. | 10 | 4 | 6.6 | 6.4 | 18.0 | 19.0 | .. | .. |
| — | — — | — - — | — | — | — | — — | 40 | 16 | — | 6.0 | — | 30.0 | 1 | 1 |
| 3384 | — 22 | N.E. of Stevns Light | 55°21′ | 12°33′ | 21 | $9^{00}$ a.m. - $9^{30}$ a.m. | 40 | 16 | 5.4 | 5.4 | 7.9 | 8.5 | .. | .. |

[1]) The opening of both gears was abt. the same, viz. 3 m².

han 15 m. (Young-Fish-Trawl used on St. 3341—49, Ring-Trawl on the rest of the stations).

| Agonus cataphractus | Cyclopterus lumpus | Liparis sp. | Gobius minutus | Gobius microps | Gobius pictus | Gobius scorpioides | Aphya pellucida | Crystallogobius nilssoni | Anarrhichas lupus | Lumpenus lampetriformis | Chirolophus ascanii | Centronotus gunellus | Gasterosteus aculeatus | Gadus callarias | Gadus aeglefinus | Gadus merlangus | Onos sp. | Ammodytes sp. | Drepanopsetta platessoides | Pleuronectes platessa | Pleuronectes flesus | Pleuronectes limanda | Clupea harengus spring spawn. | Clupea harengus winter spawn. | Clupea harengus autumn spawn. | Anguilla vulgaris | Syngnathus rostellatus | Syngnathus typhle | Nerophis aequoreus | Station No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .. | .. | 3 | .. | .. | .. | .. | .. | .. | .. | 1 | .. | 1 | .. | 15 | .. | .. | .. | 11 | 2 | 1 | .. | 1? | .. | 9 | 15 | .. | .. | .. | .. | 3341 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 6 | 1 | .. | .. | 6 | .. | 1 | .. | .. | .. | 2 | 2 | 1 | .. | .. | .. | 3342 |
| 16 | .. | 356 | .. | 3 | .. | .. | 1 | 4 | .. | 7 | 1 | 61 | .. | 325 | .. | .. | .. | 257 | 2 | 32 | 5 | .. | .. | 146 | 103 | 2 | .. | .. | .. | 3343 |
| 2 | .. | 79 | .. | .. | .. | .. | .. | .. | .. | .. | 1 | 1 | .. | 46 | .. | .. | .. | 27 | 3 | .. | 5? | .. | .. | 27 | .. | .. | .. | .. | .. | |
| .. | .. | 5 | .. | .. | .. | .. | .. | .. | .. | 1 | .. | 1 | .. | 105 | .. | .. | .. | 48 | 2 | 2 | .. | .. | .. | 3 | 10 | .. | .. | .. | .. | 3344 |
| 2 | .. | 8 | .. | .. | .. | .. | .. | .. | .. | 7 | .. | 7 | .. | 33 | .. | .. | .. | 29 | 1 | 6 | .. | 1? | .. | 22 | 8 | .. | .. | .. | .. | 3345 |
| 2 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | 3 | .. | 5 | .. | 12 | .. | .. | .. | 3 | 1 | .. | .. | .. | .. | .. | 2 | .. | .. | .. | .. | 3347 |
| 3 | .. | 15 | .. | 39 | .. | 1 | .. | 26 | .. | 9 | 1 | 13 | .. | 153 | .. | .. | .. | 18 | .. | 2 | 1 | .. | .. | 61 | 22 | .. | .. | .. | .. | 3349 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | 1 | .. | 39 | .. | .. | .. | 2 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3350 |
| 2 | .. | 3 | .. | .. | .. | .. | .. | .. | .. | 35 | .. | 46 | .. | 825 | .. | .. | .. | 52 | 1 | 8 | 6 | .. | .. | 36 | 9 | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | 3 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3351 |
| 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 5 | .. | .. | .. | 112 | .. | .. | .. | 8 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 48 | .. | .. | .. | 1 | .. | .. | 2 | .. | .. | 5 | .. | .. | .. | .. | .. | 3352 |
| .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 136 | .. | .. | .. | .. | 2 | 1 | .. | .. | .. | 74 | .. | .. | .. | .. | .. | — |
| .. | .. | 6 | .. | .. | .. | 6 | 1 | .. | .. | .. | .. | 2 | .. | 11 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | 33 | .. | 2 | .. | .. | .. | 3353 |
| .. | .. | 4 | .. | .. | 10 | 10 | .. | .. | .. | 5 | .. | 2 | .. | 15 | .. | .. | .. | .. | 1 | 1 | 1 | .. | .. | 28 | .. | 1 | .. | .. | 1 | — |
| 3 | 1 | 6 | .. | .. | .. | 18 | .. | .. | .. | 2 | 1 | 2 | .. | 83 | .. | .. | .. | 19 | 6 | 1 | 6 | .. | .. | 14 | 2 | 2 | .. | .. | .. | 3354 |
| 1 | .. | 5 | .. | 10 | 2 | 36 | .. | .. | .. | .. | .. | 2 | .. | 73 | .. | .. | .. | 15 | 4 | 1 | 1 | .. | .. | 13 | 1 | 2 | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 27 | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3355 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 13 | .. | .. | .. | .. | 2 | 4 | .. | .. | .. | 3 | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3361 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 55 | 1 | 1 | .. | .. | 13 | .. | 5 | .. | .. | 6 | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 9 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | 3362 |
| 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 5 | .. | .. | .. | 80 | 1 | .. | .. | .. | 2 | .. | 6 | .. | .. | 21 | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 5 | .. | .. | .. | 3 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3363 |
| 1 | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | 15 | .. | .. | .. | 4 | 1 | .. | 1 | .. | .. | 2 | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 2 | .. | .. | .. | 5 | .. | 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | 3364 |
| .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | 17 | .. | .. | .. | 5 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | — |
| 2 | .. | 10 | .. | .. | 1 | .. | .. | .. | .. | 15 | .. | 20 | .. | 106 | .. | .. | .. | 2171 | 1 | 1 | 25 | .. | .. | 17 | 73 | .. | .. | .. | .. | 3365 |
| .. | .. | 17 | .. | .. | .. | 5 | .. | .. | .. | 26 | .. | 10 | .. | 402 | .. | .. | .. | 353 | .. | 17 | 1 | .. | .. | 14 | 33 | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | 10 | .. | .. | .. | 5 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3368 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 26 | .. | .. | .. | 4 | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 20 | .. | .. | .. | 3 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3369 |
| 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 36 | .. | .. | 1 | 3 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 19 | .. | .. | .. | 4 | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | 3370 |
| .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 40 | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 15 | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3371 |
| 5 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 28 | .. | .. | .. | 4 | 1 | 1 | .. | .. | .. | .. | .. | .. | 1 | .. | .. | — |
| 1 | .. | 2 | 1 | .. | .. | .. | .. | .. | .. | 4 | .. | 3 | .. | 13 | .. | .. | .. | 40 | .. | 1 | .. | .. | .. | 2 | 6 | .. | .. | .. | .. | 3372 |
| 4 | .. | 2 | 7 | .. | .. | 1 | .. | 2 | .. | 6 | .. | 5 | .. | 71 | .. | .. | .. | 244 | .. | 7 | 1 | .. | .. | 1 | 24 | .. | .. | .. | .. | |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3373 |
| 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 28 | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3374 |
| .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | — |
| .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | 6 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3375 |
| .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 28 | .. | .. | .. | 4 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | — |
| 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3376 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | 5 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3377 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | — |
| .. | .. | 13 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 8 | .. | 25 | .. | .. | .. | 1571 | .. | 12 | .. | .. | .. | 1 | 19 | .. | .. | .. | .. | 3378 |
| 3 | .. | 22 | 1 | .. | .. | .. | 1 | .. | .. | 17 | .. | 7 | .. | 11 | .. | .. | 2 | .. | .. | 7 | .. | .. | .. | .. | 41 | .. | .. | .. | .. | |
| .. | .. | 21 | 10 | .. | 1 | .. | .. | .. | .. | .. | .. | 1 | 2 | .. | .. | .. | .. | 8 | .. | .. | 1? | .. | .. | .. | .. | .. | .. | .. | .. | 3379 |
| .. | .. | 11 | 8 | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | 1 | .. | .. | .. | 25 | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | — |
| .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 19 | .. | .. | .. | 1 | 1 | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | 3381 |
| 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 115 | .. | .. | .. | 1 | 6 | .. | 7 | .. | 1 | 7 | .. | .. | .. | .. | .. | |
| .. | .. | 21 | 3 | 3 | .. | .. | .. | .. | .. | 1 | .. | .. | .. | 22 | .. | .. | .. | 2 | .. | 4 | 5 | .. | .. | 2 | .. | .. | .. | .. | .. | 3381 |

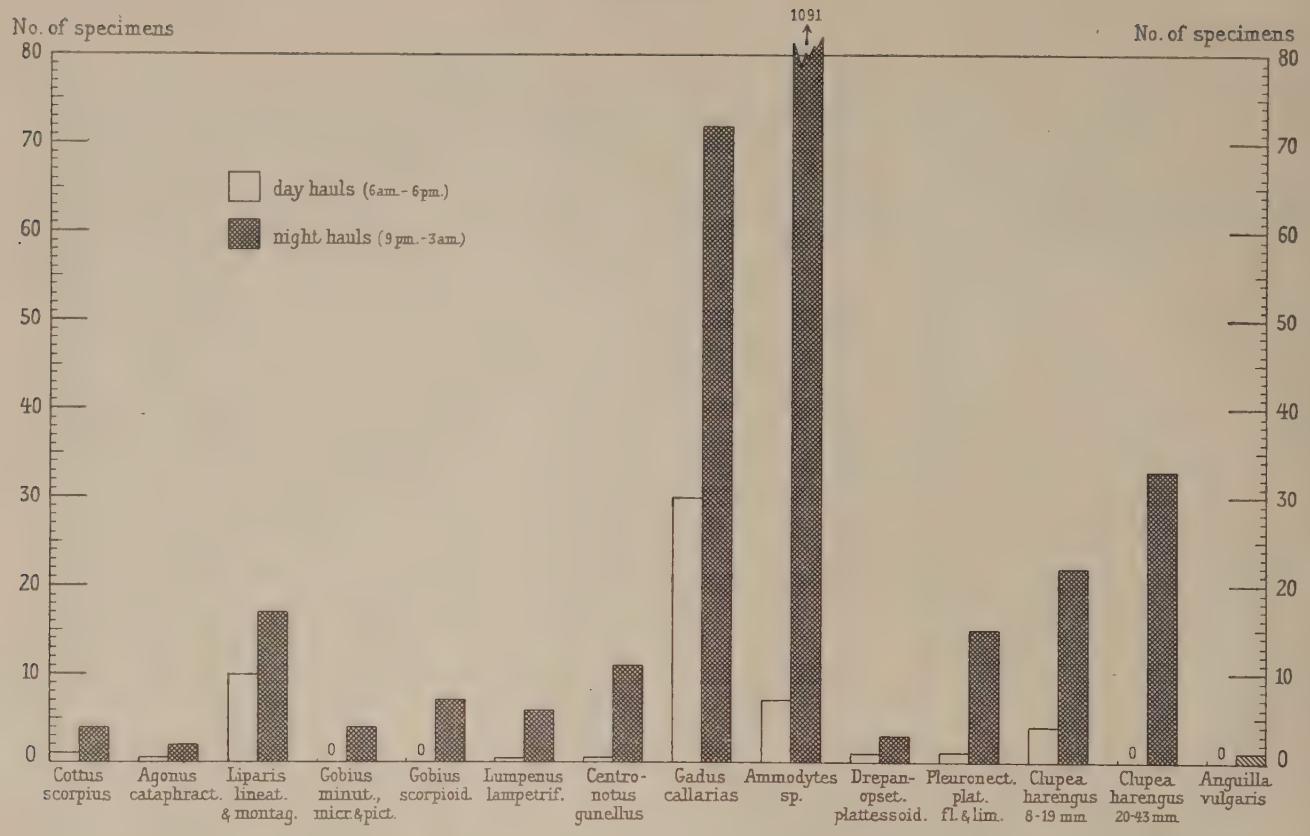


Fig. 9. Average number of larvae or young of various fish species caught per hour with ring-trawl in day-hauls and in night-hauls in the upper layer of the Kattegat, Belt Sea and western Baltic. April 1925. (About situation of the Stations see Fig. 5 p. 9).

## IV. Can any conclusions be fairly drawn, from fishing experiments with slowly moving implements, as to diurnal vertical migrations of fishes and their larvæ?

V. Franz (1911) was very sceptical as to how far existing observations warrant the assumption that fish larvæ undertake any diurnal vertical migration. He writes in this connection (p. 324):

"Angaben darüber, dass die planktonischen Fischlarven Wanderungen ausführten, sind mir keine bekannt, mit Ausnahme einer: Vom Leptocephalus brevirostris, der bekannten oleanderblattförmigen Aallarve, wird angegeben, dass sie bei Tag sich in der grössten Anzahl in einer Tiefe von ca. 100 m halte, nachts aber auch dicht an der Oberfläche angetroffen werde (Johs. Schmidt).[1]) Diese Angabe scheint meiner Vermutung zu wiedersprechen, aber es ist meines Erachtens gar keine Gewähr dafür vorhanden, dass nicht eine wichtige Fehlerquelle mitspielte. Wäre es denn nicht möglich, dass die Aallarven bei Tage das herannahende Netz sehen und ihm — obwohl sie sich sonst langsam bewegen, durch plötzliche blitzschnelle Bewegungen entweichen, während sie nachts das Netz natürlich nicht sehen können und daher auch an der Oberfläche gefangen werden? Ist diese Annahme nicht wohl wahrscheinlicher, als eine regelmässige über 100 m ausgedehnte Wanderung?

Man findet öfter die Angabe, dass auch pelagische Fische des Nachts emporsteigen. In den meisten

[1]) Johs. Schmidt: Contribution to the life-history of the Eel (Anguilla vulgaris, Flem.). Conseil permanent pour l'exploration de la mer, Rapports et procès-verbaux, Vol, V. Kopenhagen 1906.

Fällen möchte ich eine ähnliche Erklärung für diese Erscheinung annehmen, also vermuten, dass die hypothetische Wanderung garnicht stattfindet."

The view here expressed by Franz is certainly well worth consideration when dealing with fish and fish larvæ of the more swiftly moving species, but the point is less important in the case of slowly moving species. With regard to the particular instance he refers to: the apparent diurnal movements of Leptocephalus brevirostris, the probability is, in my opinion, that these movements are real enough. It seems hardly likely that these thin, leaf-shaped larvæ should be able to make sudden lightning movements and thereby escape an implement such as the ring-trawl; we have, moreover, a series of observations on record both as regards elvers and the yellow and silver eels, showing that the eel is extremely sensitive to the light. JACOBY for instance, writes (1880) with regard to the migrations of the elvers from the Adriatic to the lagoons of Comacchio: "Sie halten sich während des Tageslichtes stets auf dem Grund; bei einbrechender Dunkelheit, auch bei Tage, wenn der Himmel bewölkt ist, pflegen sie sich gegen die Oberfläche zu erheben".

The yellow eels may be seen hurrying away from the light of the lantern in the prow of the boat when eel-spearing is carried on at night; and JACOBY reports (1880) that in the lagoons of Comacchio it has been the custom for centuries to stop now and then the influx of silver eels to the eel-weirs by means of fires in front of the weirs, in order to hinder too great an accumulation. Also PETERSEN (1906) has found by experiment that the movements of the silver eels are strongly influenced by artificial light.

It is a well-known fact that the breeding migration of the silver eels in the upper water layers takes place mainly or exclusively at night. A well-known and respected Danish fisherman, P. HILDEBRANDT states (1906) that on Sept. 25, 1905, two Danish fishermen observed several hundreds of eels in the upper layer of the Great Belt at night, and that three of these specimens were caught in a catcher. They did not appear in great shoals, but came 3—4 at a time. The eels were observed about 1 a.m. two days before new moon.

C. G. JOH. PETERSEN (1924 & 1925) observed in the autumn of 1923 and 1924 silver eels, and also a few yellow eels, at night in the upper layer of the Great Belt, and some of them were captured by means of spears while swimming near the surface.

With regard to the fishing experiments with the ring-trawl mentioned in Chapters II and III, it may be doubtful whether any conclusions can be drawn from these as to diurnal vertical migrations on the part of the large, rapidly moving larvæ; it seems justified, however, in the case of the tiny larvæ. These minute, almost filiform larvæ, of herring for instance, (comp. Fig. 8 A and B) are certainly not rapid in their movements. It is likely that the actual catches made are an expression of both phenomena; firstly, that most species move upwards en masse after sunset, and secondly, that the individuals are inclined to move away from the implement when they can see it.

Numerous observations suggest that many grown up fish make similar vertical diurnal migrations to those of the larvæ. This applies, as already noted, to the eel (*Anguilla vulgaris*) and certain *Gobius* species. Many species with luminous organs are captured in the surface layers only at night. In a species such as the herring, large shoals are comparatively rarely met with at the surface during the daylight, whereas it is a well-known fact that enormous quantities are caught by drift nets in the upper water layers at night. In the case of the hake it is known that hauls made with the trawl on the bottom give far higher yield in the daytime than at night, and it is therefore generally supposed that this species lives pelagically during the night. This view has recently been confirmed by HICKLING's investigations of the stomach contents (cf. Chap. VI).

## V. On the amplitude of the diurnal vertical movements of young of fishes.

If we regard the number of young of the different fish species caught at various times of the day during the serial hauls at St. 3380 in the southern Kattegat, we notice a remarkable agreement between the catches in the upper and in the intermediate layer: in each of the layers the main catch took place

at night (comp. Tables 3 and 4 and Fig. 2—4). This fact suggests that the main part of the larvae in the day time kept below the level where the fishing in the intermediate layer took place, i. e. below 16 metres depth. Several facts brought forth during the ordinary fishing experiments with ring-trawl in April of 1925 suggest that the amplitude for the vertical movements in many cases is much greater.

At St. 3352, S. E. of the Lysegrund in the southern Kattegat, where the depth was 32 metres, we caught 6 specimens of *Gobius scorpioides* during the night, in the upper layer at about 4 metres depth (see Table 5). As we have never caught this species pelagically except during the night, there is reason to believe that it keeps to the sea floor in the day time. At St. 3354 S. W. of Anholt, where the depth was about 18 metres, we caught 18 specimens of the same species in the upper layer at about 4 metres depth.

At St. 3353, S. of Anholt, where the depth was 31 metres, we caught during the night 2 elvers (*Anguilla vulgaris*) in the surface layer, at about 4 metres depth. In the day time, when the sky is clear, we do not catch this species pelagically, where the depths are not more than 30—40 metres.

The animals which in the Kattegat undertake diurnal vertical movements of considerable amplitude, move through water layers of very different salinity. Many of the animals which in the day time keep to the sea floor, where the salinity is 30—34 ‰, occur at night in the upper layer, where the salinity may not be more than 15—20 ‰. This is the case for instance with such species as the elvers (Anguilla vulgaris), Gobius scorpioides and Gobius microps.[1]) At St. 3380 in the southern Kattegat, where the serial hauls mentioned in Chap. II were made, the salinity varied from abt. 18 ‰ in the surface to about 34 ‰ at the bottom (25 metres) while the salinity varied from 21 to 27 ‰ at 15 metres depth. Many species moved up and down from the surface to below 16 metres, and some of them — as Gobius scorpioides — moved from the bottom to the surface and back again in the course of less than 12 hours. Such species are evidently not particularly sensitive to water of different salinity, as long as it does not pass beyond a certain limit.

## VI. Causes of the diurnal vertical movements of young and grown fish.

The vertical movements of fishes may be considered from the following points of view:

1. The fish pursue plankton organisms and swimming invertebrates, which make diurnal vertical movements.

2. The amount of light at different levels affect the vertical movements of certain fishes.

3. The element of danger may count for something in the vertical movements of certain species.

We will now consider these various points separately.

1. Vertical movements occasioned by corresponding movement of plankton organisms etc.

There can hardly be any doubt but that the upward movement of fishes when darkness sets in is very largely due to their pursuit of natural food, since an upward movement takes place at night among numerous plankton organisms and many benthonic animals which serve as food for the fish. This view has already been advanced by Reinhardt (1854) who states that in 1850, in the Atlantic between 23° N. lat. and 6° N. lat., he observed that the surface after sunset begins to be crowded by vast swarms of pteropods and numerous species of crustaceans. He captured with his drag-net a pelagic fish with luminous organs: *Astronesthes fieldii* in the surface, but only at night; and he thought it probable that the fish searches for food among these animals, following them into the depths during the daytime.

Hickling states (1925) that it is a matter of common knowledge that Hake (*Merluccius vulgaris*) are pelagic at night, and leave the sea floor to hunt in the upper waters. "This is so much the case, that

[1]) This refers also to some species of Mysidæ, such as Mysis ornata, Mysis mixta and Gastrosacchus spinifer etc.

the trawlers working the distant deep-water grounds will lie hove-to all night rather than waste coal in useless fishing". — Hickling shows that *Meganyctiphanes norvegica* and other Euphausiids are much more frequent on the sea-floor by day than at night (in the Smalls area, St. George's Channel) and he gives the following explanation of the vertical migrations of the Hake:

"Small hake seem to select Meganyctiphanes, and to a less extent, Nyctiphanes, in preference to other crustacea or small fish. It seems fair to suggest that when Meganyctiphanes leaves the bottom, the small hake will follow it in its vertical migration, and thus no longer appear in the trawl. — Big hake are likewise omnivorous, but in the present case show a preference for small hake over bib (*Gadus minutus*) or smelt. I suggest, therefore, that they follow the small hake into the upper waters, where they may also find other pelagic fish, such as mackerel, horse-mackerel, and occasionally herring".

The young of the Herring feed to a very great extent on copepods (M. V. Lebour 1921, A. C. Hardy 1924) and as both the young herring and very many copepods are known to move upwards after sunset and downwards when it dawns, it seems probable that a hunting for food takes place here. Dr. Lebour (1924) has found that *Nyctiphanes Couchii* is of great importance as food for adult Herring in the Plymouth' waters. She points out that both species come to the surface at night, and she considers it probable that the Herring feed on the euphausiids at that time.

2. The amount of light at different levels affect the vertical movements of certain fishes.

It has been mentioned above that the light influences the movements of many plankton forms,[1]) and that these again are pursued by the fishes. The light has, however, also a more direct influence upon the vertical movements of certain fishes. The silver eels, for instance, do not move upwards during the night in order to feed. They take up the pelagic habit in order to continue their breeding migration, which was broken off in the day time.

It is well known that the movements of fishes in aquaria are affected by the light, and we often notice that a certain fish species show a tendency to keep either in a very dark or in a well illuminated part of the aquarium.

3. The element of danger may be a factor in the vertical migrations.

It is probable that various minor pelagic fishes have a certain tendency to keep away from the upper water layers during the day, as they are there strongly exposed to attack by dangerous enemies such as the thunny, the bonito, mackerel, salmon etc. Also the attack of sea birds may play a certain rôle in this respect in some places.

Hjort (1912) observed that *Astronesthes*, certain *Scopelids*, and other pelagic fishes from the upper water of the Atlantic Ocean occurred nearer to the surface at night than in the day time. The same was the case with certain red-coloured and dark-coloured bathypelagic fishes, and Hjort suggests that the upward and downward migrations of the dark coloured forms probably coincide so precisely with the disappearance and reappearance of daylight that the dark colouring may be of no danger to the animals in their nightly migrations.

## VII. Remarks on the diurnal vertical movements of plankton organisms.

In the above mentioned serial experiments in the southern Kattegat on the 20th and 21st of April 1925 (Chapt. II) it was observed that the quantity of plankton taken with the Hensen net in vertical hauls from 10—0 metres depth was considerably greater at night than during the day. This will be apparent from the table of captures below (measurements made by Magister P. Jespersen, who points out that they are only approximate).

[1]) See also Chap. VII.

| Haul No. | Time | Zooplankton | Phytoplankton | Total |
|---|---|---|---|---|
| I | 1 p.m. | 4 cm³ | 2 cm³ | 6 cm³ |
| II | 3 — | 6 — | 1 — | 7 — |
| III | 5 — | 7 — | 1 — | 8 — |
| IV | 7 — | 9 — | 1 — | 10 — |
| V | 9 — | 8 — | 4 — | 12 — |
| VI | 11 — | 11 — | 5 — | 16 — |
| VII | 1 a.m. | 12 — | 3 — | 15 — |
| VIII | 3 — | 10 — | 2 — | 12 — |
| IX | 5 — | 7 — | 1 — | 8 — |
| X | 7 — | 3 — | 1 — | 4 — |
| XI | 9 — | 4 — | 1 — | 5 — |
| XII | $10^{15}$ — | 5 — | 4 — | 9 — |

From this it will be seen that the Zooplankton, which consisted predominantly of copepods, has a very distinct maximum at night (cf. Fig. 10), and that the Phytoplankton (mostly Diatoms) also had a maximum at night.

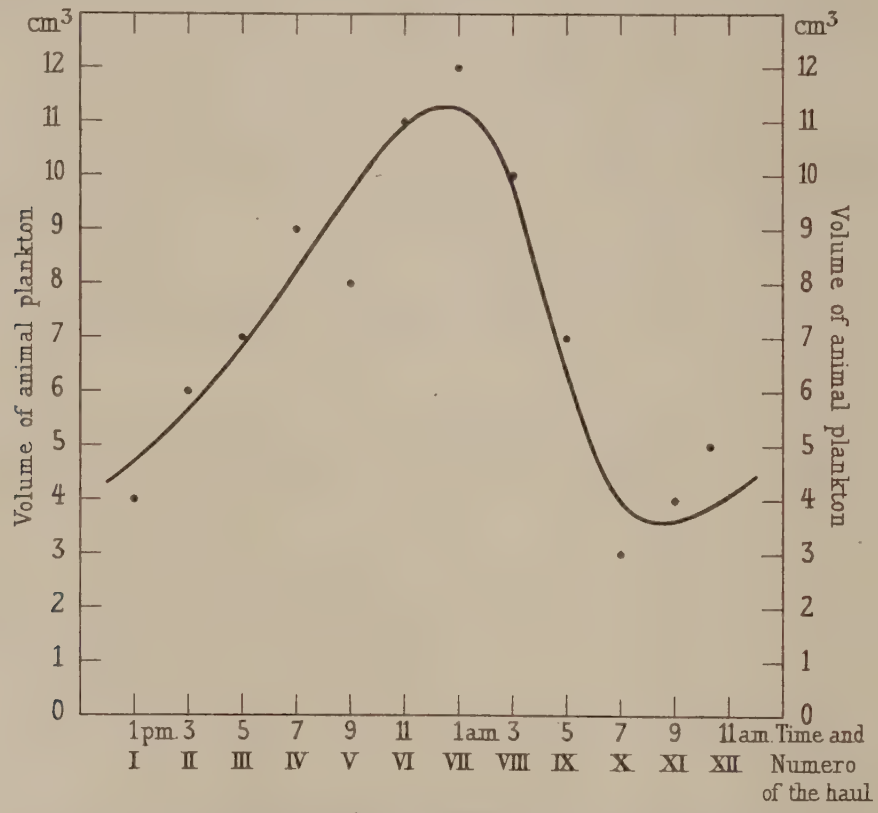


Fig. 10. Volume of animal plankton (chiefly Copepods) taken in vertical hauls with Hensen Net from 10—0 metres in the southern Kattegat at St. 3380 April 20.—21. 1925.

The diurnal vertical movements of animal plankton in nature have been dealt with by various naturalists, and it is a general experience that animals of various groups are more frequent in the upper layers at night than in the day time.

As stated in Chap. VI, REINHARDT has already in 1850 made observations to that effect concerning Pteropods and Crustaceans in the Atlantic.

LEYDIG (1860) noticed that the Entomostraceans in fresh water lakes occurred nearer the surface in the early morning and in the evening than in the day time when the sun was shining.

A. Weismann (1874) observed in the Bodensee in the summer of 1873 that the pelagic Daphnidæ *Leptodora hyalina* occurred in the surface at night, but generally not in the day time.

"Stärkeres Licht meiden sie offenbar, und bei hellem Sonnenschein kann man sicher sein, kein einziges Individuum an der Oberfläche zu finden. Auch bei Vollmond hatte ich regelmässig nur eine schlechte Beute, die beste bei trübem Wetter gegen Abend oder in dunklen Nächten". (p. 404—405).

Thomas Scott (1895—97) observed that many species of Copepods in the Gulf of Guinea occurred more frequently in the surface tow nettings collected during the night than in those collected during the day, while in the undersurface tow nettings they were of more frequent occurrence in those collected in the day time than in those collected during the night.

Steuer (1910) mentions that some benthonic coast forms leave the bottom after sunset and wander about like true pelagic animals during the night. He draws attention to the fact that the phototactic movements of many plankton organisms are in the main restricted to certain epochs of their life, and that the planktonic Crustaceans for instance are most noticeably phototactic as larvae. There may also be differences in this respect between males and females.

Esterly (1912) showed that in the San Diego region (California) 19 different species of Copepods occurred in greater abundance at night than in the day time in the upper water layer. From collections with closing nets he was able to locate the day plurimum or centre of migration, and this was never at the same depth for daylight hauls as for collections made during the night.

Hugo Behrens (1914) investigated the diurnal vertical movements of Plankton organisms in the Sakrower See, near Potsdam. He pumped water from different depths and afterwards counted and measured the animals. By this method he found, for instance, by investigations under the ice (23—24 Febr. 1912) that the maximum of Copepods in the upper layer occurred about midnight, and that at the same time a minimum occurred in the lower layers (below 10 metres). During the day time a minimum occurred in the surface and a maximum in the lower layers.

Ellis L. Michael (1911) investigated the vertical distribution of the Chaetognathæ of the San Diego Region. Concerning *Sagitta bipunctata* (Quoy et Gaim.) he was able to show that in all depths above 25 fathoms the species attains maximum abundance twice during the day, one maximum occurring between 6 and 10 a.m., and the other between 6 and 8 p.m. Below 25 fathoms only one maximum occur at each depth, and that one between 12 a.m. and 2 p.m. Between 6 p.m. and 6 a.m. the species is most abundant above 15 fms., while between 6 a.m. and 6 p.m. it is most abundant below 15 fms.

### The amplitude of the diurnal vertical movements of Plankton Animals.

At St. 3380 in the southern Kattegat, where the serial hauls were made, we noticed for the Mysidae a similar agreement between the catches in the upper and in the intermediate layers as in the case of the fish larvae (see Chap. II). Species such as *Mysis ornata* G. O. Sars, *Mysis mixta* Lilljeborg and *Gastrosacchus spinifer* Goës[1]) were taken in each of the layers exclusively in the night-hauls, between 10 p.m. and 2 p.m. This fact suggests, that these species also keep below the 16 metres level in the day time. *Gastrosacchus spinifer* has been taken in numbers in the ordinary fishing experiments with ring-trawl in April 1925 in the upper layer, at about 4 metres depth, during the night,[2]) but in the day hauls only very few specimens occurred even at depths up to 36 metres. In the experiments with ring-trawl in the Skagerak in 1923—25 and former years a very marked nightly ascent of Crustaceans such as *Meganyctiphanes norvegica* M. Sars and *Pasiphaë tarda* Kröyer was apparent, and it seemed probable that many specimens of these species rose 100—150 metres or more during the night.

The question about the amplitude of the diurnal vertical movements of Zooplankton has been dealt with by various authors:

Willemoes-Suhm (1874) mentions in a letter to Prof. v. Siebold that it was noticed in investigations

[1]) The Mysidæ were determined by Erik M. Poulsen.

[2]) ca. 100 specimens per 30 minutes' haul.

from the Challenger Expedition in the Indian and Antarctic seas that a series of pelagic animals occurred only at night in the surface, but might be caught 50—100 fms. further down in the day time.

CHUN (1888) concluded from plankton collections in the Mediterranean that *Alciopidae, Sagitta, Appendicularia* and *Coelenterata* descend about 100 metres at dawn and ascend again after sunset. The Amplitude for the diurnal movement of most plankton organisms was about 30—50 m.

CH. JUDAY (1904) gives a record of diurnal migrations observed in some lakes in south eastern Wisconsin. He states that the diurnal movements in each lake has certain individual characteristics. Thus in the various lakes, the zone deserted by *Daphnia hyalina*, Leydig, during the day varies in thickness from a quarter of a meter to seven metres, while in one lake there was no movement at all. As to the extent of the vertical movement Juday gives *inter alia* the following figures:

| | | |
|---|---|---|
| Daphnia retrocurva | maximum | 10 m. |
| Leptodora hyalina | — | 9 - |
| Bosmina | — | 4 - |
| Epischura lacustris | — | 12 - |
| Diaptomus | — | 5 - |
| Cyclops | — | 10 - |
| Limnocalanus macrurus | — | 35 (?) |

With a few exceptions, the young were nearer the surface in the daytime than the adults, and as a result their migrations were not so great.

GOUGH (1905) studied the vertical distribution of plankton organisms at various times of the day in the English Channel in July of 1903, by means of experiments with a vertical net and with GARSTANG's horizontal closing net. He found for various medusae and *Tomopteris* that the amplitude of the diurnal movement was about 30—70 metres.

A. OTTERSTRØM (1910) investigated the diurnal vertical movements of *Mysis mixta* in the Baltic near Bornholm in the summers of 1906 and 1907. He found that the main ascent takes place between 8 p.m. and 10 p.m., and that the amplitude amounted to 30—50 metres, in the waters where his investigations were made.

ESTERLY (1911) studied the diurnal migrations of *Calanus finmarchicus* in the San Diego region (California) during 1909 and arrived at the following results:

1. *Calanus finmarchicus* is most abundant at the surface about 7 or 8 p.m. during June and July.[1])

2. It has begun to leave the surface by midnight, and is most abundant at a depth of 5 or 10 fathoms about midnight, as judged from horizontal collections below the surface with closing nets.

3. The plurimum during the day (6 a.m. to 6 p.m.) is probably at 200 fathoms.

As to the causes of the diurnal vertical movements of Zooplankton it seems probable that the light in most cases is a factor of prime importance.

GROOM and LOEB (1891) noticed that the Naupliae of *Balanus perforatus* when kept in glasses sometimes moved towards and sometimes away from the source of illumination. Naupliae which had been kept in darkness for some time were "positively heliotropic", and those which for some time has been exposed to light of a certain intensity, became "negatively heliotropic".

The authors found the same peculiarity in a larva of the Chaetopods, but not in the Copepods.

HJ. DITLEVSEN (1906) made experiments in aquaria concerning the reaction of planktonic animals to light. He found that both fresh water forms and salt water forms show a tendency to seek the lightest place in the aquarium. The various light-qualities act principally in the same manner. The rays with the shortest waves have the greatest "photopathic" effect; thus blue light is preferred to red light.

Ditlevsen experimented also with some fresh water animals not belonging to the plankton, and he

[1]) GOUGH (1905), on the other hand, arrived at the result in the Channel that *Calanus finmarchicus* seemed to be influenced by light in just the reverse manner to the other copepods. "During the hottest part of the day the surface water swarmed with Calanus; after sunset it dispersed through all layers".

found that one of these viz. the Daphnidæ *Polyphemus pediculus*, was strongly phototactic. The movements of *Polyphemus* could be completely directed by a coloured glass-plate. The rays which struck it released the reaction immediately whether they were red or blue. The red rays seemed to repel the animals as strongly as the blue attracted them.

E. Naumann (1921) showed by experiments in long cylinder glasses, where the source of illumination was placed sometimes above, and sometimes below the glasses, that the stratification of plankton consisting of *Daphnia*, *Polyphemus* and *Bosmina* etc. was dependent upon their reaction to the light. The various forms showed here great differences with regard to the amount of light present in the level where they mainly occurred.

The diurnal vertical movements of many planktonic animals is probably connected with their search for food. M. V. Lebour (1924) states that *Nyctiphanes Couchii* taken at night in the upper water layer had been feeding on diatoms, with Sagitta and Crustacea: "The fact that Nyctiphanes from the surface contained more food than those from near the bottom points to their coming to the surface to feed".

W. E. Allen (1920) in his quantitative and statistical study of the plankton of the San Joaquin River found that two pulses of chlorophyll bearers were closely accompanied by similar pulses of Protozoa and of Rotifera. He noticed also that there was an abrupt decrease in green organisms as Entomostraca increased, which was followed by a partial recovery after the entomostracan maximum.

Variation in the specific gravity of the plankton organisms, caused among others by the metabolism, is probably a factor of some importance for the diurnal rise and fall. Dora Eyden (1923) has made the observation that *Daphnia pulex* increases in specific gravity immediately after feeding and diminishes after starvation. Miss Eyden found that the specific gravity varied in animals of the same size at different periods of the day and night, attaining a maximum shortly after sunrise and reaching minimum between 10 p.m. and 4 a.m. and a second less well defined minimum about midday.

Karl Brandt (1885) found by experiments that the specific gravity of the Sphærozoa (e.g. *Collozoum inerme*) greatly depends on the size and number of the vacuoles, and that the animals are able to diminish or enlarge the vacuoles. The alterations in size and number of the vacuoles could be caused by mechanical and thermic stirring.

"Die Vacuolenflüssigkeit kann nicht direkt in das Meerwasser entleert, sondern muss zunächst in die Gallerte diffundirt sein ... Während nach kurzer und nicht zu heftiger thermischer Reizung die Kolonien wieder in wenigen Stunden zur Oberfläche des Wassers emporsteigen, dauert es oft 2—3 Tage, bis nach lange andauernden oder sehr heftigen thermischen Reizen die Individuen wieder auseinander gerückt sind, und die Kolonie wieder so zahlreiche Vacuolen enthält, dass sie emporsteigen kann ... Die Bewegungen der Pseudopodien spielen bei dem Auf- und Niedersteigen der Kolonie eine wichtige Rolle, jedoch eine andere, als Häckel, annahm. Sie wirken nicht direkt auf das umgebende Wasser, sondern tragen durch Vergrösserung oder Verringerung des Umfanges der Vacuolen zur Erniedrigung resp. Erhöhung des specifischen Gewichtes der Kolonie bei".

It is not known, however, whether the Radiolarians generally undertake diurnal vertical movements. Geddes (1882) states that they have the habit of leaving the surface and sinking into deep water early in the day, but this has been contradicted by other authors.

Ostwald (1902) emphazises that the velocity of the sinking of the plankton organisms depends upon 1) the difference between their specific gravity and that of the water, 2) their shape[1]) and 3) the viscosity of the water. The viscosity decreases when the temperature increases. The upward movement has an active character and is achieved by promiscous wandering.

It should be remembered, however, that the diurnal variation in the viscosity of the water caused by variations in temperature is restricted to a thin surface layer.

The diurnal vertical movements of *chlorophyll bearers* are but little known. Johnstone, Scott and Chadwich state (1924) that diatoms are phototactic, and our serial hauls in the upper layer at St. 3380 in

[1]) Ostwald (1904) suggests, that the temporal variation of the *Daphnidæ* should be seen in the light of the varying viscosity of the water.

the southern Kattegat in April of 1925 showed a well marked maximum at night as in the case of the zooplankton (see p. 20). It is too early, however, from the few observations to hand to draw general conclusions regarding an agreement between the diurnal vertical movements of zooplankton and of phytoplankton. New investigations are strongly needed.

## VIII. On a tendency of pelagic fish larvæ and other plankton organisms to assemble in shoals or swarms.

It is a well-known phenomenon that numerous species of fish, even while still young, move in shoals; thus for instance the herring, sprat, coalfish, whiting, goby, stickleback etc. This tendency to gather in shoals is doubtless manifested already in the larval stage, as the irregular yield of the serial

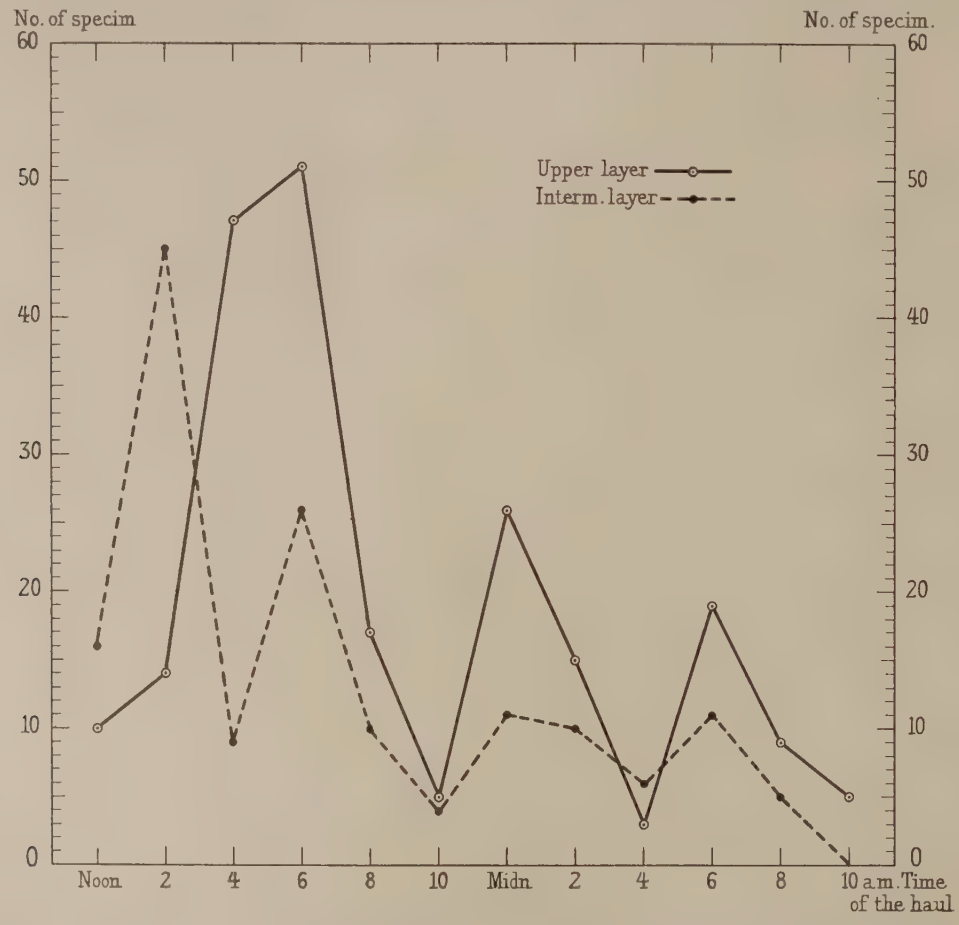


Fig. 11. Number of larvae of Cod (*Gadus callarias* L.) of 4—9 mm length caught pr. 30 minutes' haul with ring-trawl at St. 3380 in the southern Kattegat. April 20.—21. 1925.

hauls in the southern Kattegat appears to suggest in some cases. A glance at Fig. 4 (p. 8) showing the number of herring larvæ of 10—18 mm taken with the ring-trawl in serial hauls in the southern Kattegat during the spring of 1925 at once gives the impression of this shoal formation; and the same holds good in the case of the cod (Fig. 11). This shoal formation can at times somewhat obscure the typical picture of the alternating frequency of the species in the surface layer as a result of the diurnal vertical migrations.

In the ordinary fishing experiments with the ring-trawl also, several observations were made which distinctly suggest shoal formation in the case of the larvæ. Thus for instance the fishing experiments at St. 3378 in the Arkona Basin, where hauls were made from 8.15 to 8.45 p.m. at two different depth simultaneously, using the ring trawl with 30 and 90 metres of wire respectively (see Table 5). The haul with 30 m.w. yielded 1571 larvæ and young of *Ammodytes* (from 13 to 91 mm) and that with 90 m.w. brought up not a single *Ammodytes* (but numerous other fish larvæ). In view of the fact that the trawl shot with 90 m.w. had to pass through the same level as the trawl with 30 m.w. when hauled in, it is inexplicable that there should have been no larvæ in the haul from the greater depth, unless it be assumed that the larvæ were congregated in shoals to a very marked degree.

In the case of invertebrates also, an irregularity was observed in the numbers caught, suggesting that many of the species congregate in swarms. In the serial hauls with the ring-trawl in the southern Kattegat (St. 3380, 20.—21. April 1925) the volume of plankton from the upper and intermediate water layers[1]) measured in $cm^3$, was as follows:

| Haul | Time | Upper layer | Intermediate layer |
|---|---|---|---|
| I | 12 noon | 2 $cm^3$ | 2 $cm^3$ |
| II | 2 p.m. | 3 — | 4 — |
| III | 4 — | 3 — | 80 — |
| IV | 6 — | 3 — | 165 — |
| V | 8 — | 25 — | 5 — |
| VI | 10 — | 25 — | 75 — |
| VII | 12 midnight | 3 — | 5 — |
| VIII | 2 a.m. | 40 — | 60 — |
| IX | 4 — | 50 — | 60 — |
| X | 6 — | 5 — | 5 — |
| XI | 8 — | 5 — | 5 — |
| XII | $9^{15}$ — | 2 — | 3 — |

It was a single species which was responsible for the bulk of the volume in those hauls which yielded large quantities of plankton, the species in question being *Pleurobrachia pileus* Fabricius.

The salinity in the upper layer varied less than 0.5 ‰ during the experiments. The salinity in the intermediate layer at 15 metres depth varied from about 21 to 27 ‰. (See Table 1 p. 4).

At St. 3380, a series of vertical hauls were made with the Hensen net from bottom to surface (see p. 3—4). The yield from these hauls measured in $cm^3$ — was as follows:

| | | | |
|---|---|---|---|
| I | 1 p.m. | 37 $cm^3$ | Phytoplankton dominating |
| II | 3 — | 84 — | |
| III | 5 — | 110 — | |
| IV | 7 — | 53 — | |
| V | 9 — | 63 — | |
| VI | 11 — | 51 — | |
| VII | 1 a.m. | 60 — | |
| VIII | 3 — | 31 — | Zooplankton dominating |
| IX | 5 — | 12 — | |
| X | 7 — | 36 — | |
| XI | 9 — | 19 — | |
| XII | $10^{15}$ — | 25 — | |

It will be noticed that the catch here albeit the hauls were made throughout the whole column of water, was nevertheless so irregular that there can hardly be any doubt as to the swarm formation. It

[1]) It will be noted that the average yield in the intermediate layer was far greater than in the upper water layer, viz. 39 $cm^3$ as against 14 $cm^3$.

is noticeable also, that the phytoplankton predominates in the first seven hauls, whereas in the last five, the zooplankton is predominant, and a decline in the average volume is observed.

In the upper water layers (10—0 metres), the occurrence of the Plankton in swarms was not so pronounced as to obscure the regular diurnal vertical movements (see p. 19—20).

The writer is indebted to Messrs. P. Jespersen, Aage J. C. Jensen, Erik M. Poulsen and Anton Fr. Bruun for valuable assistance. M. Aage J. C. Jensen has undertaken the hydrographical and meteorological observations published in the Tables 1, 2 and 5.

# List of Literature.


Winfred Emory Allen: A quantitative and statistical study of the Plankton of the San Joaquin river and its tributaries in California, in 1913. — University of California Publications. in Zoology. Vol. 22. Berkeley 1920.

Hugo Behrens: Die vertikale Verteilung des Crustaceenplanktons. Inaug.-Dissertation. Berlin 1914.

Karl Brandt: Die koloniebildenden Radiolarien des Golfes von Neapel. Fauna und Flora des Golfes von Neapel. XIII. Monographie. Berlin 1885.

Anton Fr. Bruun: On the development and distribution of the Norway Bullhead (*Cottus lilljeborgi* Collett). — Publications de Circonstance. Cons. perm. internat. No. 88. 1925.

Carl Chun: Die pelagische Tierwelt in grösseren Meerestiefen und ihre Beziehungen zu der Oberflächenfauna. — Bibliotheca Zoologica Bd. I. Heft 1, Cassel 1888.

Hj. Ditlevsen: Forsøg over nogle Planktondyrs Forhold overfor Lys. — Oversigt K. Danske Vid. Selsk. Forh. 1906. No. 2.

Calvin O. Esterly: Diurnal migrations of *Calanus finmarchicus* in the San Diego region during 1909. — Internat. Rev. ges. Hydrobiol. und Hydrogr., Bd. 4. 1911.

— The occurrence and vertical distribution of the Copepoda of the San Diego region. — University of California. Publications in Zoology. Berkeley. Vol. 9. No. 6. Sept. 1912.

— Reactions of various Plankton Animals with reference to their diurnal migrations. — ibd. vol. 19. No. 1. April 1919.

Dora Eyden: Specific Gravity as a factor in the vertical distribution of Plankton. — Proc. Cambridge Phil. Soc. (Biol. Sciences) Vol. 1. No. 1. 1923.

V. Franz: Phototaxis und Wanderung. Nach Versuchen mit Jungfischen und Fischlarven. — Internat. Revue gesamt. Hydrobiol. u. Hydrographie Bd. III. 1910/11.

Patrik Geddes: Further researches on Animals containing Chlorophyll. Nature. Vol. 25. 1882 (cited after Brandt).

Lewis H. Gough: Report on the Plankton of the English Channel in 1903. — Mar. Biol. Assoc. Internat. Fishery Investigations. Southern Area. First Report. London 1905.

Groom und Loeb: Der Heliotropismus der Nauplien von *Balanus perforatus* und die periodischen Tiefenwanderungen pelagischer Tiere. — Biol. Centralblatt. Bd. X. 1891.

A. C. Hardy: The Herring in Relation to its Animate Environment. — Fishery Investigations. Ser. II. Vol. VII. No. 3. Londou 1924.

Fr. Leydig: Naturgeschichte der Daphniden. Tübingen 1860.

C. F. Hickling: Notes on Euphausiids. — Journ. Marine Biol. Assoc. Plymouth N. S. Vol. XIII No. 3. March 1925.

P. Hildebrandt: Vandrende Aal. — Dansk Fiskeritidende No. 4. 1906.

Johan Hjort: (see Murray and Hjort).

L. Jacoby: Der Fischfang in der Lagune von Comacchio, nebst einer Darstellung der Aalfrage. Berlin 1880.

A. C. Johansen: Remarks on the Life History of the young post-larval Eel. — Medd. Komm. f. Havundersøgelser. Ser. Fiskeri. Bd. I. No. 6. 1905.

James Johnstone, Andrew Scott and Herbert C. Chadwich: The marine Plankton. Liverpool 1924.

Ch. Juday: The diurnal movements of plankton crustacea. — Trans. Wis. Acad. Sciences XIV. 1904.

Marie V. Lebour: The food of young Clupeoids. — Journ. Mar. Biol. Assoc. Plymouth. Vol. XII. No. 3. 1921.

— The Euphausiidæ in the Neighbourhood of Plymouth and their Importance as Herring Food. ibd. Vol. XIII. No. 2. 1924.

Ellis L. Michael: Classification and Vertical Distribution of the Chaetognatha of the San Diego region. — University of California. Publications in Zoology. Berkeley. Vol. 8. No. 3. Dec. 1911.

John Murray and Johan Hjort: The depths of the Ocean. London 1912.

Einar Naumann: Untersuchungen über das Verteilungsproblem des limnischen Biosestons 1. — K. Sv. Vet. Akad. Handlingar 61. 1921.

Wolfgang Ostwald: Zur Theorie des Planktons. — Biologisches Centralblatt. XXII Bd. Leipzig 1902.

— Experimentelle Untersuchungen über die Saisonpolymorphismus bei Daphniden. — Archiv f. Entwicklungsmechanik d. Organismen. Leipzig 1904.

Andreas Otterstrøm: Beobachtungen ueber die senkrechten Wanderungen des Mysisbestandes in der Ostsee. — Medd. Komm. f. Havundersøgelser, Ser. Plankton. Bd. 1. No. 9. 1910.

C. G. Joh. Petersen: The influence of light on the migrations of the Eel. — Report XIV from the Danish Biological Station. 1906.

— Rapport over Biologisk Stations Virksomhed i 1923. — Fiskeri-Beretning for 1923, Kjøbenhavn 1924.

— Beretning om Biologisk Stations Virksomhed i 1924. — Fiskeri-Beretning for 1924. Kjøbenhavn 1925.

J. Reinhardt: Tvende Iagttagelser af phosphorisk Lysning hos en Fisk og en Insektlarve. — Vid. Medd. Naturh. Foren. Kjøbenhavn for 1853. 1854.

Johs. Schmidt: Contributions to the Life-History of the Eel. — Rapports et Proces-Verbaux. Cons. perm. internat. Vol. V. 1906.

Thomas Scott: Report on Entomostraca from the Gulf of Guinea. — Transac. Lin. Soc. London. 2. Ser. Vol. VI. Zoology 1894—97.

A. Steuer: Planktonkunde. Leipzig u. Berlin 1910.

A. Weismann: Ueber Bau und Lebenserscheinungen von *Leptodora hyalina*, Lillj. — Zeitsch. f. wissensch. Zoologie. Bd. 24. Leipzig 1874.

Willemoes-Suhm: Von der Challenger-Expedition. Briefe an C. Th. E. von Siebold. — Zeitschrift für wiss. Zoologie. 24. Bd. Leipzig 1874.



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